NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

BENEFITS OF MULTICASTING APPLICATIONS WITHIN THE UNITED STATES MARINE CORPS

by

Mark A. Flournoy

June 1999

Thesis Advisor:	Syed Ali
Associate Advisor:	Terrance Brady

Approved for public release; distribution is unlimited

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1999	Master's Thesis

4. TITLE AND SUBTITLE
Benefits of Multicasting Applications within the United States Marine Corps

5. FUNDING NUMBERS

6. AUTHOR(S)
Flournoy, Mark A.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

This thesis investigates the efficiency of multicasting, a relatively new network technology that allows low bandwidth delivery of real-time and archived information. Bandwidth efficiency is derived from relieving the transmission source from the current burden of transporting and replication of a unique data stream for each individual recipient. Voice, video, and data are carried in a single transmission on any transport medium to any number of preselected users or group of users.

It will allow commanders a synchronized, real-time logistics and intelligence information capability for making critical force employment decisions. In addition, multicasting's open standard architecture allows it to run over almost all of DoD's existing communication infrastructure.

Research concentrates on the specific technologies and supporting equipment necessary to provide effective delivery of real-time or on-demand multimedia without major costs to the user and in compliance with the Defense Information Infrastructure/Common Operating Environment (DII/COE). While technical specifics are discussed, this paper focuses on the characteristics of multicasting that can increase the Marine Corps' combat and administrative effectiveness. With the increasing need to save time and money, multicasting offers a substantial advantage over currently used technologies.

14. SUBJECT TERMS
Multicasting, Network-based Video, Streaming Video, MPEG, United States Marine Corps

15. NUMBER OF PAGES
94

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFI- CATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std.

Page Intentionally Left Blank

BENEFITS OF MULTICASTING APPLICATIONS WITHIN THE UNITED STATES MARINE CORPS

Mark A. Flournoy
Captain, United States Marine Corps
B.S., Auburn University, 1990

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
IN
INFORMATION TECHNOLOGY MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1999

Author: ______________________
Mark A. Flournoy

Approved by: ______________________
Syed Ali, Thesis Advisor

____
Terrance Brady, Associate Advisor

____
Reuben Harris, Chair
Department of Systems Management

Page Intentionally Left Blank

ABSTRACT

This thesis investigates the efficiency of multicasting, a relatively new network technology that allows low bandwidth delivery of real-time and archived information. Bandwidth efficiency is derived from relieving the transmission source from the current burden of transporting and replication of a unique data stream for each individual recipient. Voice, video, and data are carried in a single transmission on any transport medium to any number of preselected users or group of users.

It will allow commanders a synchronized, real-time logistics and intelligence information capability for making critical force employment decisions. In addition, multicasting's open standard architecture allows it to run over almost all of DoD's existing communication infrastructure.

Research concentrates on the specific technologies and supporting equipment necessary to provide effective delivery of real-time or on-demand multimedia without major costs to the user and in compliance with the Defense Information Infrastructure/Common Operating Environment (DII/COE). While technical specifics are discussed, this paper focuses on the characteristics of multicasting that can increase the Marine Corps' combat and administrative effectiveness. With the increasing need to save time and money, multicasting offers a substantial advantage over currently used technologies.

Page Intentionally Left Blank

TABLE OF CONTENTS

Page Intentionally Left Blank

LIST OF TABLES

Page Intentionally Left Blank

LIST OF FIGURES

Page Intentionally Left Blank

LIST OF ACRONYMS AND ABBREVIATIONS

AAR	After Action Review
ADSL	Asynchronous Digital Subscriber Line
ARG	Amphibious Readiness Group
ATM	Asynchronous Transfer Mode
ATO	Air Tasking Order
CDROM	Compact Disk Read Only Memory
COC	Combat Operations Center
CTP	Common Tactical Picture
DII/COE	Defense Information Infrastructure/Common Operating Environment
DoD	Department of Defense
DVMRP	Distance Vector Multicast Routing Protocol
FPS	Frames Per Second
CODEC	Compression Decompression
GCE	Ground Combat Element
GM	General Motors
GPS	Global Positioning System
HTML	Hyper Text Transfer Protocol
IGMP	Internet Group Multicast Protocol
IP	Internet Protocol
IS	Instrumentation System
ISDN	Integrated Services Digital Network
IT21	Information Technology 21st Century
JTF	Joint Task Force
Kbps	Kilobytes per second
LAN	Local Area Network
WAN	Wide Area Network
MAGTF	Marine Air Ground Task Force
Mbps	Megabytes per second

MOS	Military Occupational Specialty
PME	Professional Military Education
MOSPF	Multicast Open Shortest Path First
MOUT	Military Operations in Urban Terrain
MPEG-1	Motion Picture Expert Group One
MPF	Maritime Prepositioning Force
NCO	Non-Commissioned Officer
NEF	Naval Expeditionary Force
NT	New Technologies
OA	Objective Area
OMFTS	Operational Maneuver From The Sea
OODA	Observe, Orient, Decide, Act
OPFOR	Operational Force
OSI	Open Systems Interconnect
PKI	Public Key Infrastructure
RSVP	Resource Reservation Protocol
RTCP	Real Time Control Protocol
RTP	Real Time Protocol
SATCOM	Satellite Communication
SGML	Standard Generalized Markup Language
SOA	Sustained Operations Ashore
SONET	Synchronous Optical Network
STOM	Ship To Objective Maneuver
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
URL	Universal Resource Locator
VSAT	Very Small Aperture Terminal
VTC	Video Teleconferencing

ACKNOWLEDGMENT

The author would like to thank Professor Syed Ali and LtCol Terrance Brady for their academic and professional guidance in developing the direction and content of this thesis.

I. INTRODUCTION

A. BACKGROUND

A quote from General Charles Krulak, 31st Commandant of the United States Marine Corps:

> ...When combined with a command and control system oriented towards rapid decision-making at all levels of command, the additional speed and flexibility offered by these new techniques translates into a high tempo of operations. ...There is no single solution -- technological, doctrinal, organizational or otherwise -- which will fulfill our requirements. Only through a blending of many emerging ideas, will we attain a mature capability to carry maneuver warfare. [Ref. 1]

The United States Marine Corps is comprised of more than 174,000 active duty Marines, 42,000 reserve Marines, and 18,000 supporting civilians. These personnel are stationed throughout the United States and across the globe. Currently, communicating to, collaborating with, and training such a dispersed organization is accomplished at high cost, with disparate equipment, and varying degrees of success. Communications within the Marine Corps take the form of physical meetings, physical distribution of documents and media, telephony, radio, videoconferncing, e-mail, and message traffic. All incur some cost to the user and produce a demand on available resources. Training involves expenditures not only in production of physical media but also its distribution and transformation from information to knowledge. Redundant personnel at multiple sites produce tremendous overhead. The Marine Corps needs more flexibility without sacrificing mission effectiveness and high-quality training standards.

The complexity of our future battlefield and the vast amount of dynamic information in it will eventually make assimilation and cognition of information the primary challenge to combat success. Concentration on technologies and other means that

aid personnel in selecting and understanding information through awareness of both friendly and enemy strengths and weaknesses will be essential. Also required will be decentralized system operation and availability through networks similar to the existing Internet, in which information is made available to the user as it is created or as events occur.

The number of information resources is increasing at an astounding rate with an explosion of new applications and technologies within the last few years. These sources include sensors that are deployed in space, on manned and unmanned aircraft, with the ground forces, and at sea. They are fielded and operated by a complex network of civilian and military agencies, including:

- The Central Intelligence Agency (CIA),
- The National Security Agency (NSA),
- The National Reconnaissance Office (NRO),
- The Defense Intelligence Agency (DIA),
- The Defense Aerial Reconnaissance Office (DARO),
- The National Image and Mapping Agency (NIMA).

All of these agencies have access to diverse resources and mission responsibilities under national, regional, and local directives.

The flow of information to and from all these sensors must be networked so that data derived from the multiple sources can be effectively used to decrease the decision cycle time of combat or support commanders. As an example, under current unicast methods the exchange of information among sensors and transmission of the raw or processed information to users require communication networks that have enormous

capacity, in both bandwidth and data rate. Although it is difficult to specify the information transmission capacity needed it is fair to say that demand currently exceeds supply.

While commanders know their information needs, networks and computers quickly bog down and become congested when large amounts of information are replicated and sent across the network over and over again to multiple recipients. New convergence applications which transmit voice, video, and data promise to increase the commanders situational awareness. However, they are being transmitted across networks whose underlying design was built for simple one-to-one email or file transfer. The method of unicasting is described below.

1. Unicasting

This one-to-one transmission process is called unicasting and it is a waste of bandwidth and consequently money. Each recipient of data on a unicast network requires a separate set of data packets replicated from the original message or file (see Figure 1-1). As an example, a 1Megabyte file sent to 10,000 users requires 10 Gigabits of replication of the original 1Megabyte file. In addition to simple file transfers, it is important to note that most current collaborative network applications are delivered via unicast at a minimum bandwidth of 28.8 Kbps and as high as 1.5Mbps. The minimum bandwidth load on a local area network at any given point can be calculated by multiplying the stream or file bandwidth by the number of users receiving the stream. The network load quickly degrades performance on a standard Ethernet network. As an example of the problem, a shared 10 Mbps Ethernet network, with a usable bandwidth of 4 Mbps becomes congested with just 8-10 users viewing a video file with a bandwidth

requirement of 384Kbps (the IT-21 baseline for collaboration), and completely overwhelmed with a dozen users [Ref. 2].) Analyses of network traffic have discovered that as much as 75% of the information on some LANs or intranets is duplicated [Ref. 3]. Technically efficient and economic information distribution methods are sorely needed. Multicasting offers a solution.

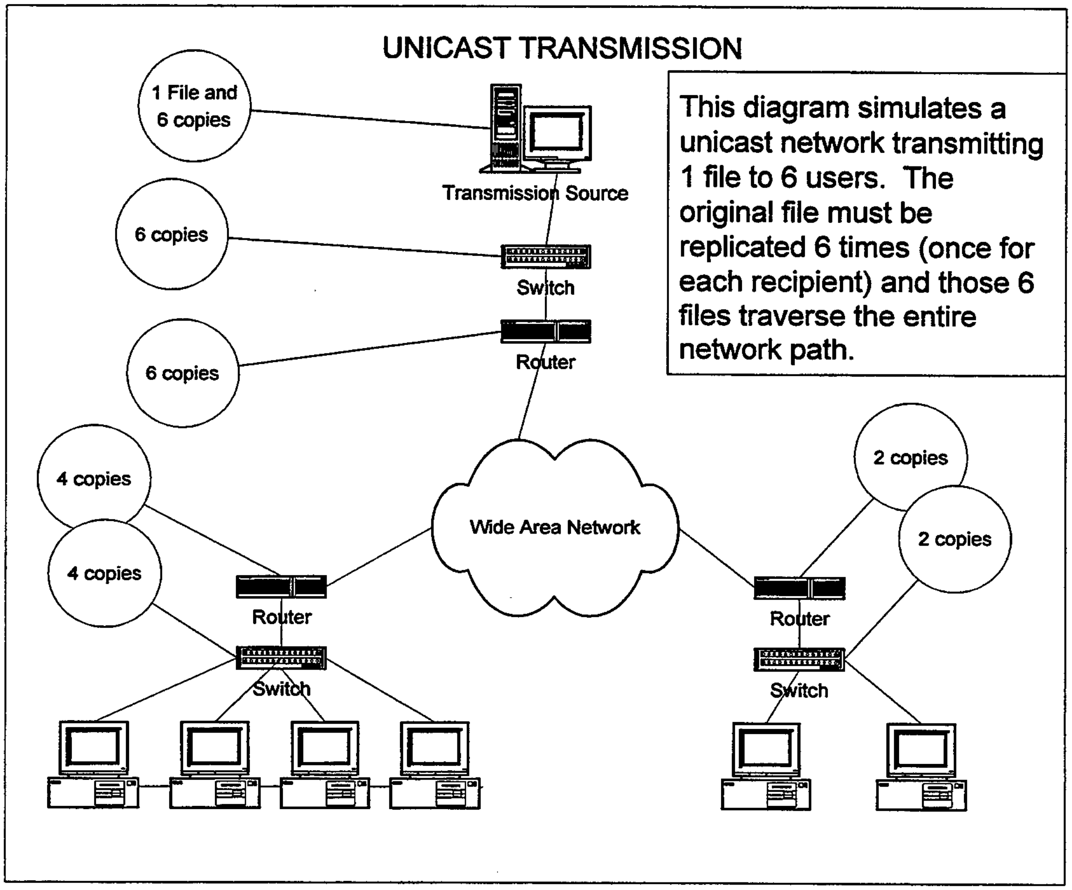


Figure 1-1 Unicast Transmission

2. Multicasting

Multicast (one-to-many) communication protocols have emerged to help as an improved technology for both real time and archived information delivery. Multicast can be looked upon as a bandwidth multiplier for networks, reducing replicated traffic by orders of magnitude. Multicasting forwards one originating data packet to an unlimited

number of designated group addressed receivers, as opposed to unicasting's forwarding of multiple replicated transmission content from the source, thus offering a substantial bandwidth savings. A more detailed description of multicasting begins in Chapter 2. [Ref. 4].

B. PURPOSE

The Defense Information Systems Agency (DISA) has specified that all new communications equipment and technologies adhere to the Defense Information Infrastructure Common Operating Environment (DII/COE), which is a communication architecture of interoperable systems (Table 1). The DII encompasses information transfer and information/processing resources, including information and data storage, manipulation, retrieval, and display. It represents all of the information technology components within DoD both in operational and supporting organizations. More specifically, the DII is the interconnected system of computers, communications, data, applications, security, people, training, and other support structure, that enables DoD's personnel to communicate. The DII: (1) connects DoD mission support, command and control, and intelligence computers and users through voice, data, imagery, video and multimedia services, and (2) provides information processing and value-added services to subscribers over DISN. [Ref. 16] Approved DII/COE computing platforms include UNIX or the Windows NT operating system. The Windows NT operating system has built-in multicasting capabilities [Ref. 12]. In addition, multicasting is already DII/COE compliant by virtue of its Internet Protocol structure. It functions within the parameter of the OSI 7 Layer model and most major vendors, to include Cisco Systems and 3Com, include multicasting capabilities as a standard option on their routers.

NEEDS	UNICAST	MULTICAST
GLOBAL REACH	✓	✓
SECURITY	✓	✓
INTEROPERABILITY	✓	✓
FLEXIBILITY	✓	✓
REAL TIME INFORMATION		✓
INFORMATION ON DEMAND		✓
INFORMATION FUSION		✓
REDUCED USER COMPLEXITY		✓

Table 1 DII/COE Specifications

The purpose here is to show how beneficial multicasting is and how it conforms to the DII/COE environment. Perhaps one of the greatest benefits of multicasting is its potential to turn every desktop computer into a networked-based real time information transceiver. Most multicasting applications have user-transparent network management controls embedded within its software. Through the use of Standard General Markup Languages (SGML), the recipient's desktop computer requires little or no special hardware or software besides the standard Web browser interface. Multicasting's ability to send audio and video to every Marine's computer with little increase in bandwidth demand will enhance communication, information delivery, and knowledge transfer while at the same time reducing costs. This paper concentrates on the real-world applications of multicast technology. It does not rely on the future availability of high bandwidth technologies. Low data rate connectivity and distance related latency are real world problems and are far from being completely resolved, especially at the tactical level. The thesis will focus on the specific technologies and supporting equipment necessary to provide effective delivery of real-time or on-demand multimedia without major costs to the user and in compliance with the DII/COE. Rather than focus on

technical specifics the paper explores the characteristics of multicasting that can increase the Marine Corps' combat and administrative effectiveness.

C. SCOPE

The scope will include: (1) An overview of multicasting protocols, networking equipment, and transmission methods. (2) A review of successful implementation of multicast networks and applications within DoD and private industry. (3) A discussion of potential Marine Corps applications of multicasting in support of both operational and administrative objectives. (4) A review of the benefits of multicasting compared to current practices. (5) A recommendation for inclusion of multicasting technologies within the United States Marine Corps' communication infrastructure.

D. METHODOLOGY

The research methodology includes: (1) Describing the essentials of multicast technologies available and applications that enhance productivity and operational effectiveness. (2) Describing multicast applications for a given mission requirement. (3) A few examples of successful implementation of multicasting services to include case studies of the Army Rangers' Military Operations in Urban Terrain (MOUT) training facility, General Motors' information distribution network, and the Microsoft Corporation's product development network. (4) Determining the cost/benefit of inserting multicast technology and its associated software applications into a given network environment.

Page Intentionally Left Blank

II. THE ESSENTIALS OF MULTICASTING

The complexity of implementing multicasting solutions varies from network to network. The principles of multicasting are described below.

A. MULTICASTING

Multicast (one-to-many) communication protocols have emerged to help as an improved technology for both real time and archived information delivery. Multicast can be looked upon as a bandwidth multiplier for networks, reducing replicated traffic by orders of magnitude. As shown below in Figure 2-1, multicasting forwards one originating data packet to an unlimited number of designated group addressed receivers, as opposed to unicasting's forwarding of multiple replicated transmission content from

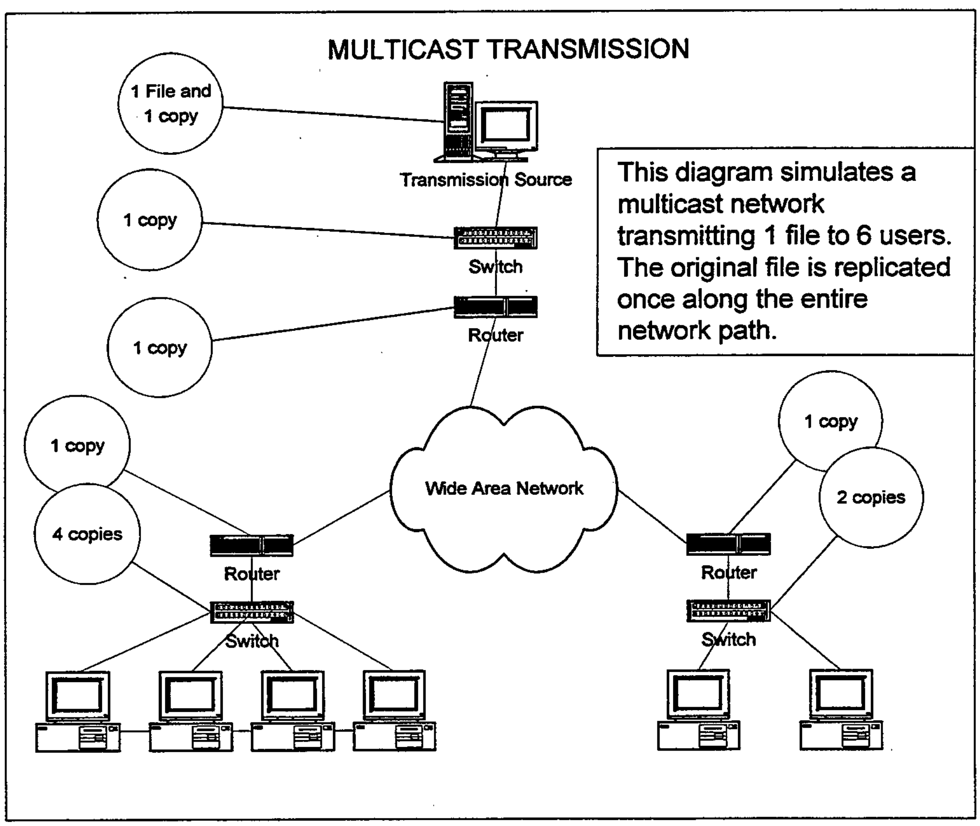


Figure 2-1 Multicast Transmission

the source, thus offering a substantial bandwidth savings. Multicasting is an optimum and cost effective method of delivering information, live or archived.

The Multicast protocol is a standard extension to the Internet Protocol (IP), which specifies the format, addressing and routing of messages on the Internet. IP Multicast allows a sender to transmit a single message to a group address. Any receiver that joins the network under this group address receives the message. The replication and forwarding of the message to the appropriate receivers is handled by multicast-enabled routers within the network. As shown in Figure 2-2, IP Multicast reduces the load on both the sending and receiving networks. IP Multicast greatly extends the efficiency of standard IP and thus reduces associated costs. [Ref. 4].

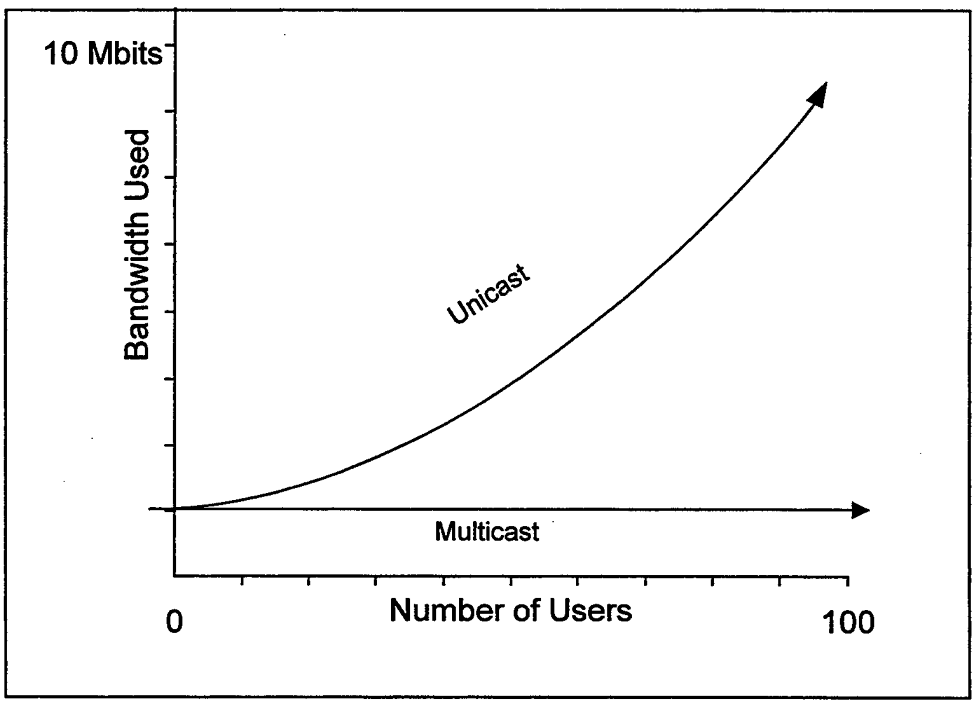


Figure 2-2 Bandwidth Comparison

A number of essential components associated with deploying a multicast enabled network are described below.

1. Protocols
2. Transmission Methods
3. Standards
4. Supporting Hardware
5. Software Applications
6. Administrator and User Skill Development.

B. PROTOCOLS

As was stated in Chapter I, there are three basic types of Internet Protocol addresses - unicast, broadcast, and multicast. A unicast address is designed to transmit a set of packets to a single destination. Each different destination or recipient requires generation of an additional set of data packets. A broadcast address sends a single transmission to every user on a network. A multicast address is designed to enable the delivery of a single transmission of data to an unlimited, but restrictive, number of users that are members of a multicast group. This helps to reduce bandwidth usage compared with standard unicast or broadcast delivery methods. This ability enables more economical transmission and delivery of multimedia, including audio, video, and real-time data. Multicasting can support thousands of simultaneous users while affecting only a small portion of overall network capacity. Multicast can run over almost any network infrastructure including dial-up modems, Ethernet, Digital Subscriber Line (DSL), Asynchronous Transfer Mode (ATM), microwave, and satellite. [Ref. 3].

1. Internet Group Management Protocol (IGMP)

Implementing a multicast topology begins with a server running a multicast application such as video or other real-time data. The server sends data to a user without the user requesting it. This is often referred to as "push" distribution. The more common distribution method on the Internet is "pull" where a user requests data from a server before the server sends the information. E-mail is an example of a "push" application. Web pages are examples of "pull" applications where a user submits a Universal Resource Locator (URL) and receives the data from the URL's source, usually in the form of a web page. The server is assigned a Class D multicast address instead of the more familiar Class A, B or C addresses (Figure 2-3). A Class D address has the range of 224.000 through 239.255.255.255. This range is translated at the network layer (layer 3) of the International Standards Organization (ISO) seven-layer Open Systems Interconnection (OSI) reference model, (Figure 2-4). [Ref. 17]

The seven-layer model provides a standard way of explaining how computer systems communicate over a network. It details what needs to be done and which device or protocol will do it. Each layer has one or more protocols specific to that layer that interact with the layers above and below it. Platforms and technologies adhering to the OSI model can be assured of interoperability with other OSI compatible devices. The network layer is the layer that is most important to multicast traffic. The primary task of the network layer is to provide protocols for the routing of packets from a local area network to another destination network. In this layer a multicast-enabled router receives a data packet and matches, or maps, it to an address at the data link layer. The data link

layer then matches the incoming set of packets to a particular computer's network interface card. [Ref. 17]

The user is also assigned a Class D address which identifies him as a member of the multicast group. The multicast-enabled router will only duplicate and forward a data packet if there are multicast users on its network. [Ref. 17] If a multicast user turns off Class D addressing, the router will cease to forward information to that particular user. This is a key point in that it results in considerable bandwidth savings for the receiving network. Without multicasting, a network would have to employ broadcasting to send traffic to multiple recipients. This would result in unwanted data packets forwarded to every user on the network, seriously overloading network resources. With multicasting, members of multicast groups get efficient transmission of data, while nonmembers can use the network without fear of slow responses or degraded service.

1	**1**	**0**	**Network ID**	**Host ID**

Class C Unicast Addressing

1	**1**	**1**	**0**	**Preselected Group Address**

Class D Multicast Addressing

Figure 2-3 Multicast Addressing Scheme

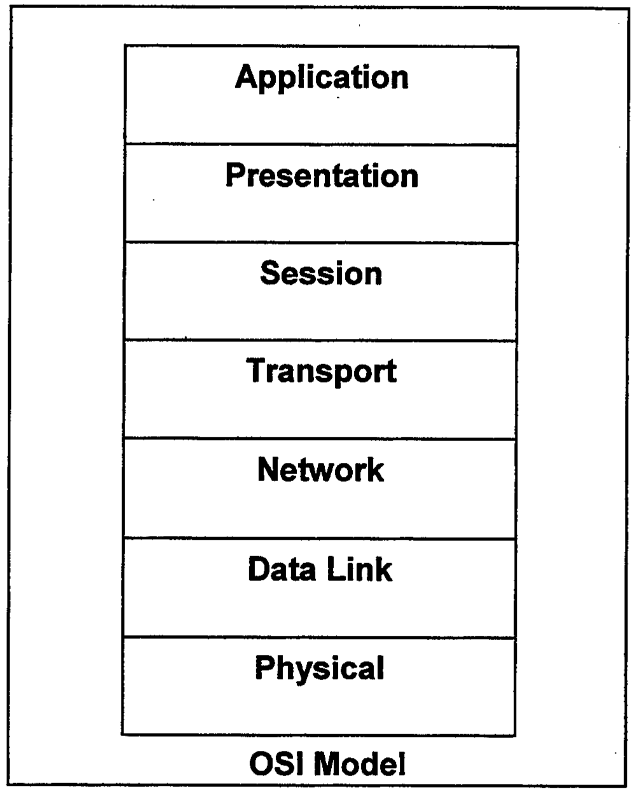


Figure 2-4 OSI Seven-Layer Model

Multicast traffic is sent from the transmission source to a host group. A host group is a collection of users which has a dynamic membership, meaning people can join or leave the group at any time. Members of a host group are also able to be members of other groups simultaneously. Each member of a host group registers with the transmission source to let the source know they want to be included in the multicast session. This is not a physical registration by the user, but is coordinated through the multicast application's software. [Ref. 6] This means there is no network-associated learning curve involved with being a user of the multicast application. In fact, most application interfaces are very similar to Internet web pages with point and click

hyperlinks. The standard protocol used is the Internet Group Management Protocol (IGMP). A user's host application, such as the Windows Media Player or Cisco's IPTV, sends an IGMP report encapsulated in an IP datagram to the user's LAN router. From there, the router communicates the information with other routers until the IGMP reaches the transmission source. [Ref. 7]

To ensure the router knows who is in a host group, it periodically sends an IGMP query to all the hosts on its network, dynamically updating membership. Each host must then respond with an reciprocal IGMP if it wants to continue being a member of that particular multicast group. If no IGMP reports are received from a user, then no multicast traffic is sent to that user. IGMP specifies that routers interact with one another to exchange information about neighboring routers. A single router is selected as the Designated Router for each LAN; these routers then construct an association referred to as a spanning tree to connect all the routers within a multicast group. This spanning tree produces "branches" when new users join a multicast group. [Ref. 9]

As these branches are created, multicast data is replicated based on the number of users per router. If a router has no users, the branch is no longer needed to replicate data and is deleted or "pruned" from the spanning tree.

2. Distance Vector Multicast Routing Protocol (DVRMP)

Many different IP multicast routing protocols and algorithms are in use. The two main types are Dense and Sparse mode protocols. Dense-mode protocols are used in .networks where bandwidth is relatively plentiful and there is at least one multicast group member in each LAN. They initially assume that all hosts are part of a multicast group, sending out traffic until they are informed otherwise and then the spanning tree is pruned.

Examples of dense-mode protocols include Distance Vector Multicast Routing Protocol (DVMRP), Multicast Open Shortest Path First (MOSPF), and Protocol Independent Multicast-Dense Mode (PIM-DM). [Ref. 10] Sparse-mode protocols begin with the assumption that few routers in the network will be involved in any multicast. They minimize network traffic by adding branches to the spanning tree only when requested to do so by a user (see Figure 2-5).

In addition to registration protocols, multicast networks must use different transport protocols than unicast traffic. Whereas Transmission Control Protocol/Internet Protocol (TCP/IP) is the most common protocol combination, or stack, used for Internet communication, multicasting requires a slightly more complex set. The protocols must be capable of translating addresses, copying and forwarding data packets, and identifying members of a multicast group. Unlike unicast, which uses TCP/IP, multicasting uses higher level protocols which establishes virtual connections. TCP retransmits any data that gets lost and resequences any data that gets delivered out of order. It sends an acknowledgment that a user has received the requested data packet. This can cause delays in real-time traffic such as voice and video; therefore, multicast does not use TCP. Retransmission of lost packets is the responsibility of the application transmitting and receiving the multicast traffic. These applications must perform their own error checks and quality of service requests. [Ref. 7]

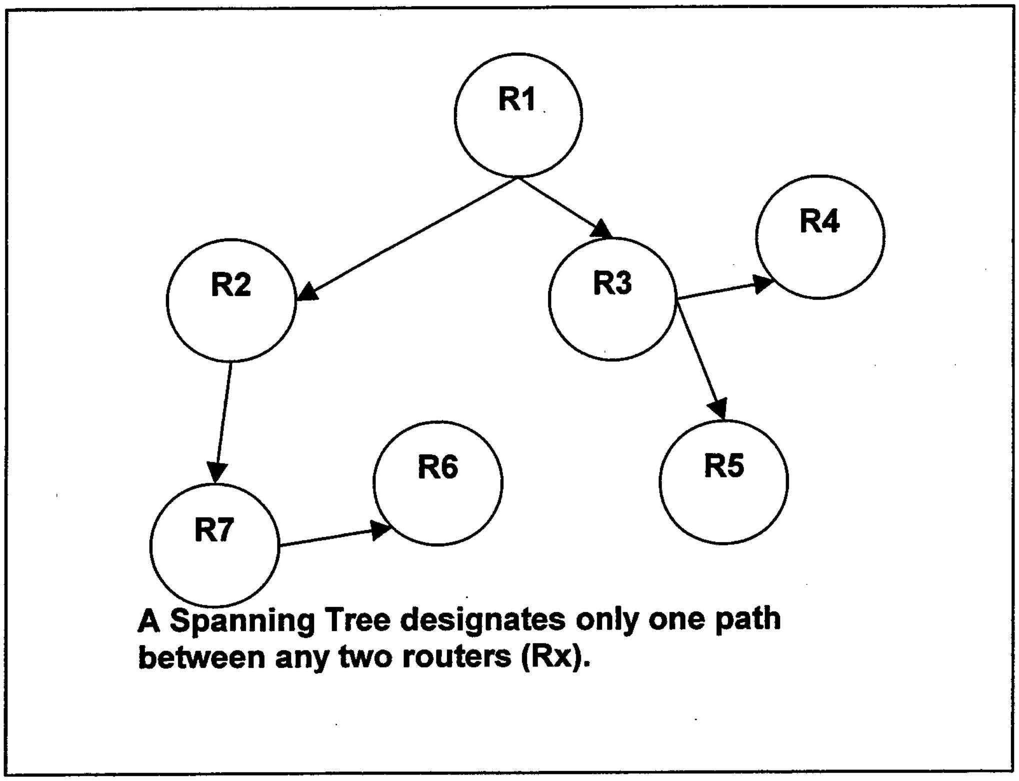


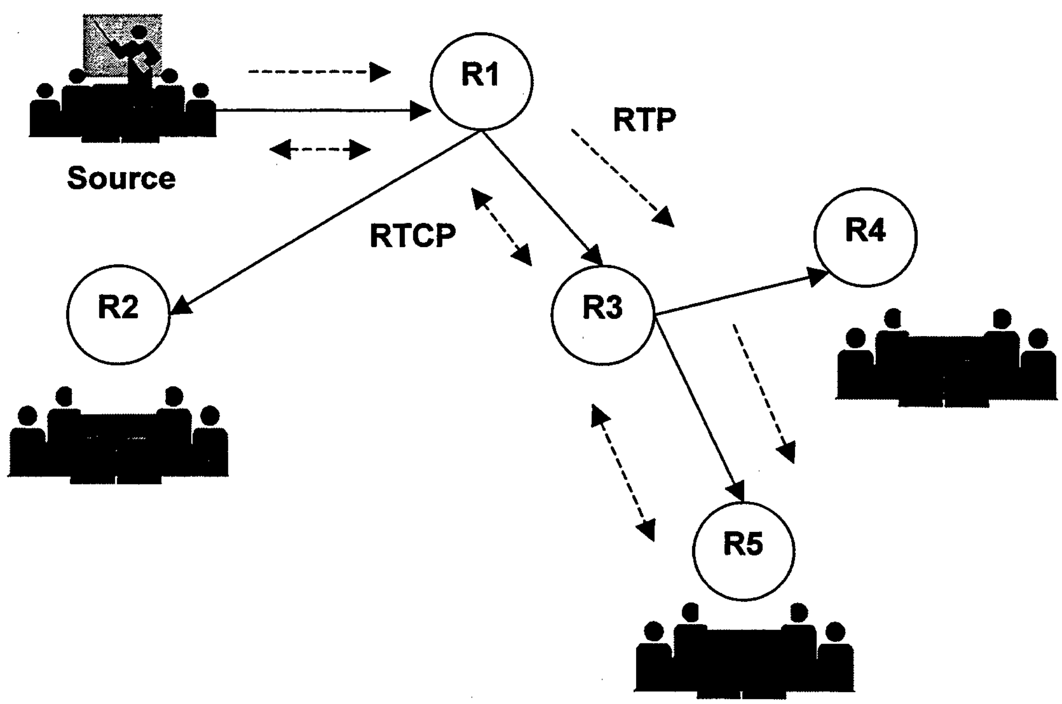
Figure 2-5 Spanning Tree

3. Real Time Protocol (RTP)

Though many multicast applications feature loss-tolerant data such as audio or video, some kind of feedback mechanism is still desirable. Real-Time Transfer Protocol (RTP) provides one answer to this problem. RTP provides a time stamp associated with each data packet which allows the receiving application to determine the proper sequence of incoming data. It does not provide any feedback to the transmission source. RTP can keep feedback traffic to 5 percent or less of overall session traffic. When any user station detects that it has failed to hear a sequenced packet, it waits for a random interval, then it sends a report back to the sender and to all other users. If, while waiting to send a report, it hears one from another user, it will cancel its own report. [Ref. 7]

4. Real Time Control Protocol (RTCP)

Another protocol used in multicasting is the Real Time Control Protocol (RTCP). RTCP does not deliver data by itself, but instead uses RTP as a transport protocol. RTCP acts as a framework for controlling multiple data delivery sessions, helping switch between TCP, UDP, and RTP sessions as required (see Figure 2-6). This quality can be used to provide interactivity between the sender and recipient. This can be used for text based messaging to augment a live multicast or, with a properly constructed interface, can provide VCR-style controls such as pause, fast-forward, reverse for a previously recorded video, or audio stream. [Ref. 11]



RTP provides a time stamp to help receiving groups sequence multimedia content. RTCP provides feedback of reception quality to the source application.

Figure 2-6 Real Time Protocol

C. TRANSMISSION MODES

The simplicity of the digital format allows transmission over a number of differing networks and it can be multicast on almost any media including fiber, Ethernet, cable, and satellite [Ref. 3]. This section will discuss the essential transmission options available in today's market. Table 2 at the end of this section lists the bandwidth capacities of each transmission mode.

Although both the digital video and the communication infrastructure for multicasting exist, there are some technological complications. Existing communication networks have been optimized to carry voice and data, not video. The nature of video and the size of video files means that existing telecommunications networks have to meet specific requirements to transmit video successfully. Video requires large, continuously flowing streams of data to successfully play back clear, moving pictures, and this causes problems, especially over large, distributed networks.

By their very design, networks are shared resources in that many users compete for a limited amount of bandwidth. As additional users logon and send or receive traffic on a unicast network, all network communication is degraded. With normal text messages or binary files, a few seconds delay in the delivery of a datapacket is not crucial as long as the entire message comes through in its original format. With video, the opposite is true. Because video is time dependent, the file will be distorted if the video transmission has to wait for other traffic to go through first. Multicasting overcomes some of these limitations by decreasing the load on the transmission source's network.

The prices of leasing high bandwidth lines is also a major constraint to wide implementation of real time data networking. In the commercial sector, demand for real

time and on demand digital video is being driven by the need to communicate with a distributed workforce in the most efficient manner possible. Many vendors are developing low cost solutions for these problems but are still restricted if employing a standard unicasting application. Below is a brief description of multicasting transmission modes.

1. Integrated Services Digital Network (ISDN)

ISDN is a set of standards for high speed digital transmission over standard telephone lines and other media. It combines analog and digital data on the same network allowing voice, video, and data transmission along a single path. ISDN has two types of services, Basic Rate Interface (BRI) and Primary Rate Interface (PRI). BRI provides two 64kbps channels while PRI provides 23 64kbps channels. ISDN transmission uses circuit switching. [Ref. 17] This means that connections are dedicated for the duration of a call and there is very little delay on the line. Most Internet transmission methods use packet switching where data is divided into packets and switched over the public network or LAN. Without multicasting, packet switching is not suitable for video transmissions because packets can be delayed or dropped when the network gets congested. Most Video Teleconferencing facilities use ISDN because it can simultaneously transmit voice, data, and video. The associated cost however is high when looking at its typical application as a non-shared resource. [Ref. 12]

2. T-1

Although T-1 was originally defined as the transmission of twenty four 64kbps channels over a 4-wire copper path, it has come to define any transmission service providing a capacity of 1.544 Mbps [Ref. 8]. This includes microwave, fiber, and coaxial

cable. T-1 lines provide sufficient bandwidth to transmit quality MPEG-1 video. The T-1 protocol is defined as constant delay transmission. This means that data is delivered at specific time intervals, which means time dependent data such as video can be transmitted. Another reason T-1 is good for transmitting video is the fact that there is no mis-sequencing. This means that all data packets are delivered in the correct order. [Ref. 6] The Marine Corps can take advantage of already existing T-1 networks without having to incur greater expenditures for specialized video networks. In addition it can maximize a network's resources through multicasting's ability to provide a constant maximum bit rate for its applications. [Ref. 13]

3. Asymmetric Digital Subscriber Line (ADSL)

ADSL, a new modem technology, converts existing twisted-pair telephone lines into access paths for multimedia and high speed data communications. The acronym ADSL, refers to ADSL modems and ADSL lines. ADSL modems are located on either end of a twisted-pair copper line, usually a telephone line, that provides asymmetric (one-way) transmission of data. [Ref. 8] This means information can be sent to the user at up to 8 Mbps and from the user to the transmitter at up to 800 Kbps depending upon line distance and the capabilities of the particular modem. ADSL modems transmit three separate frequency channels over the same line. One channel carries telephone, the second carries a 16 to 640kbs data signal upstream from a user's location, and the third channel is a high-speed downstream connection running anywhere from T1 (1.544 Mbps) to 8 Mbps. Data rates depend on a number of factors, including the length of the copper line and its wire gauge (see Figure 2-7). [Ref. 8] ADSL lines are good for video transmissions because of their broad bandwidth and because they incorporate forward

error correction that dramatically reduces errors caused by noise. An error correction code is attached to each block. The receiver then corrects errors that occur during transmission up to the limits implied by the code and the block length. This overcomes some of the protocol limitations associated with multicasting. [Ref. 7] ADSL technology is relatively new and services are just becoming widely available. While it is an emerging means for distributing high volume data, it is presently limited to fixed facility installation and is not currently capable of tactical employment.

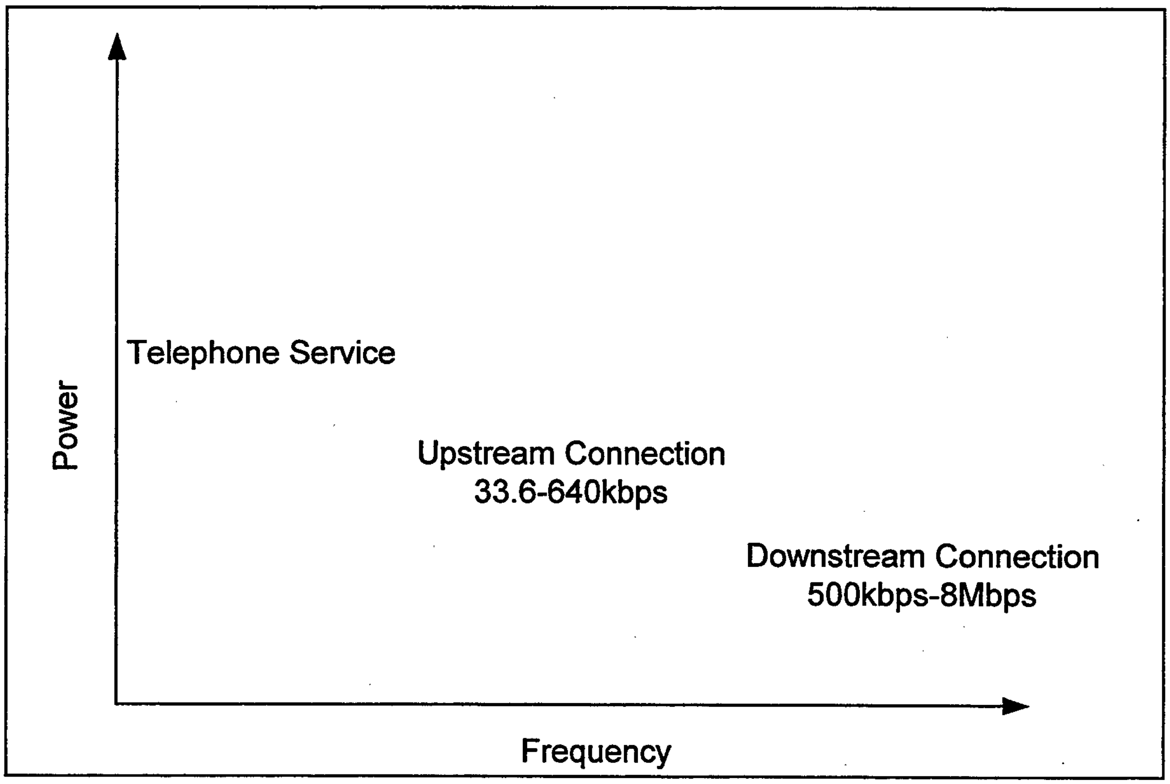


Figure 2-7 Services over ADSL

4. Asynchronous Transfer Mode (ATM)

ATM is a high speed data transmission technology standard for LANs and WANs. ATM supports high speed transmission rates of all kinds of data, including voice and video (see Figure 2-8). Using optic fiber networks, like SONET (Synchronous

Optical Network) data distribution over ATM can reach up to 622 Mb/s. One of the biggest advantages of ATM is that it can be used in both local and wide area networks. [Ref. 17] ATM does not specify a particular physical transmission media and therefore supports many different existing protocols through circuit emulation. It takes voice and video data, breaks it up into 53-byte cells, and transmits them over high-speed circuits. Both sender and receiver must have the same equipment to reconstruct the information from the 53-byte cell. ATM is suited to real time transmission because of its high bandwidth, its fixed packet transmission method and the ability to dedicate a specific bandwidth to an application. High bandwidth ATM transmission will become prevalent when fiber optic networks are installed and become widely available. It is not currently an alternative for tactical distribution of data. [Ref. 15]

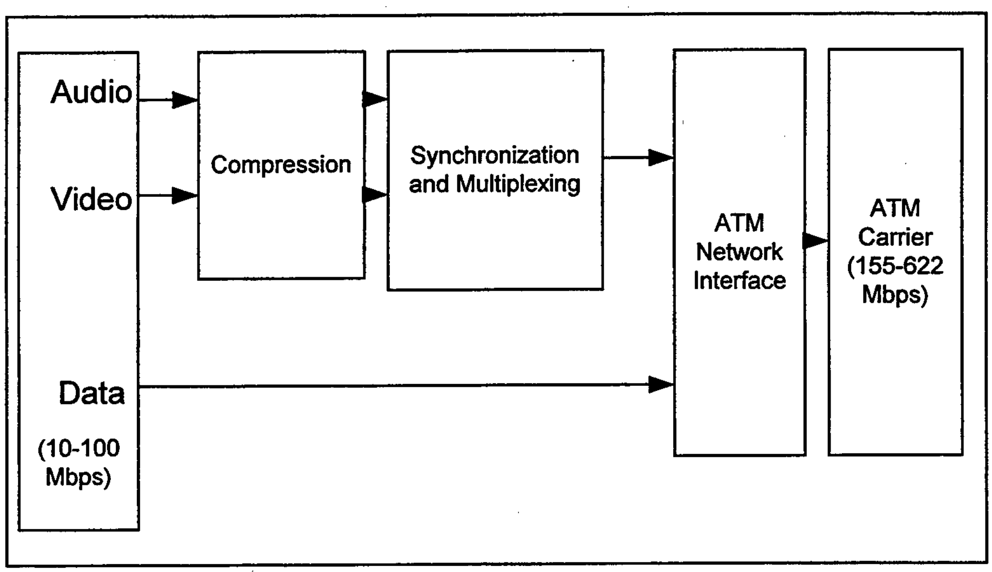


Figure 2-8 ATM Transmission

5. Microwave

A microwave link does not require any physical media for transportation and usually consists of two antennas that transmit and receive electromagnetic waves between each other. The antennas require line of site paths. The maximum range for a terrestrial microwave link is dependent on terrain but is usually limited to 90km. A much longer range can be attained by using troposcatter, such as the Marine Corps' TRC-170 which uses the ionosphere to reflect radio transmissions (see Figure 2-9). Microwave links broadcast frequencies ranging from 2-25 gigahertz and are an alternative where copper or optical cable systems are not feasible. Microwave links are often cheaper than physical cable links because they bypass traditional transmission service providers and they are relatively inexpensive to install. They can carry between 8 and 34 Mb of data per second which is more than suitable for video transmission. [Ref. 8] Another advantage of microwave is its rapid deployability in a tactical environment. High bandwidth microwave links exist within the Marine Corps at the Marine Expeditionary Force level for communication to higher, adjacent, and supporting units. The Marine Corps has low-bandwidth (less than 32kbps) organic Microwave assets distributed down to the regimental level. While these are not currently capable of handling high volume data, multicasting can maximize their throughput. The Marine Corps is very familiar with the employment of microwave paths and it represents perhaps the best transmission source of choice for initial deployment of multicasting applications connecting a distributed tactical Wide Area Network. As will be shown in Chapters III and IV, there are many multicast applications that can take advantage of low-bandwidth transmission paths.

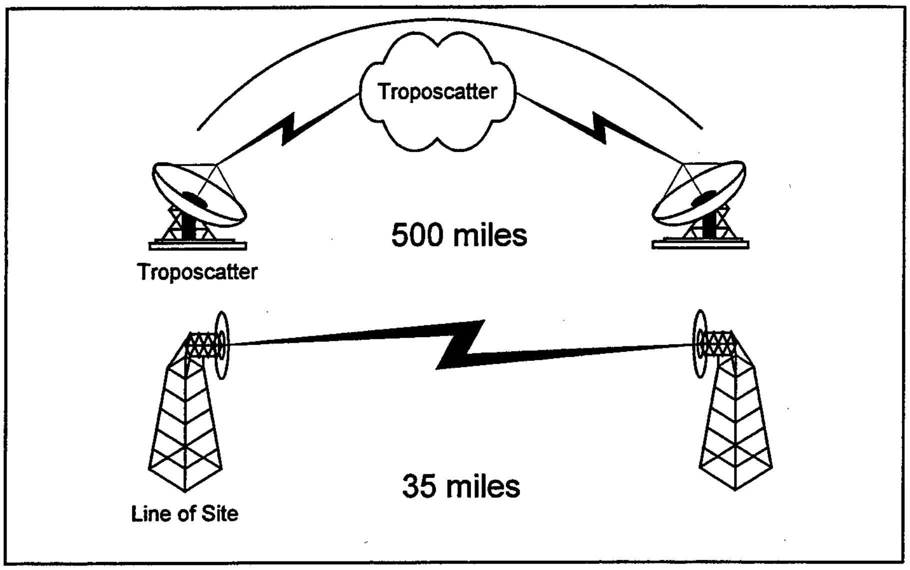


Figure 2-9 Microwave Transmission

6. Satellite Communication (SATCOM)

SATCOM systems transmit signals from earth based transceivers (transmitter/receiver) to orbiting satellites. Ground station antennas aimed at the satellite transmit hundreds of multiplexed channels to and from the satellite. Satellite transmissions are single to multi-point transmissions, that is, the signal is beamed from one to many points (see Figure 2-10). [Ref. 8] This makes satellite particularly well-suited for multicasting applications. It's also more cost-effective than T1 for sending data over a largely distributed area.

Already many satellite broadcasters are planning or introducing multicasting services. Satellite offers a number of advantages for distribution of this type of material. It's inherently a wide-area one-to-many broadcast medium, enabling data to be received at almost any number of sites through a single transfer – one satellite channel servicing many locations. It also avoids packet switching bottlenecks and guarantees bandwidth availability, which is needed for real-time video. Satellites offer the coherence of a single network regardless of destination country and local infrastructure. In addition to these

benefits, most vendors offer fixed service costs regardless of number of sites and locations. [Ref. 17]

One limitation to satellite service is the uplink limitation of users. Satellite broadcast is essentially a one-way process. Back haul access is still usually limited to other methods, such as telephone lines. Some vendors offer a low-speed asymmetrical return path, to request retransmission of dropped packets or files.

Tactical and strategic satellite receiver assets exist at almost every level within the Marine Corps. Chapters III and IV will show real world employment of multicasting applications over narrowband satellite networks. Again, satellite transmission is ideal for multicasting because of its natural broadcast characteristics It costs as much to send to a single site as it does to many, so the larger the network, the more likely that satellite will be the best alternative. It is also ideal for tactical employment as its infrastructure is already existent within the Marine Corps command and control architecture. [Ref. 17]

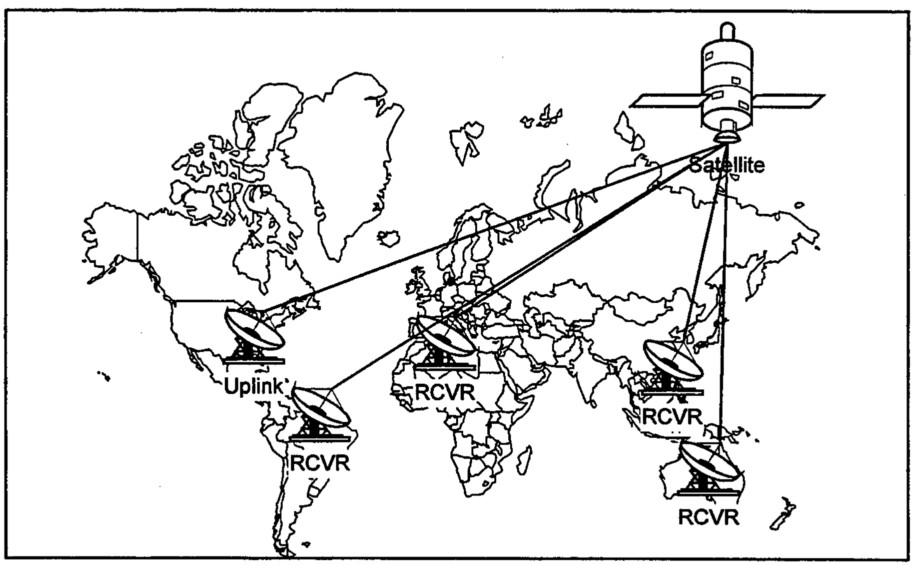


Figure 2-10 Satellite Transmission

MODE	BANDWIDTH
ISDN	2 Mbps
T1	1.54 Mbps
ADSL	8 Mbps
Ethernet	10 Mbps (100 Mbps for Fast Ethernet)
Microwave	32 Mbps
ATM	155 Mbps
Satellite	Practically unlimited at 768 Kbps/per Transponder

Table 2 Transmission Bandwidths

D. SECURITY AND ENCRYPTION

Security concerns of multicasting are similar to those in any other network architecture, the difference being the reception by only members of a predetermined group of interested users. Authentication and verification of these users can be accomplished through username and password schemes or through use of a Public Key Infrastructure (PKI) [Ref. 17]. As with other digital information, multicast material can be bulk encrypted for transport over a network. With the additional overhead resulting from encryption, network management, and larger file sizes, it is necessary to identify the value of various compression techniques.

E. COMPRESSION

Compression plays a crucial role in increasing bandwidth savings. Due to its design, most current Ethernet networks cannot carry raw digital video. An uncompressed 24 bit color video, with 640 x 480 pixel resolution, at a television quality 30 frames per second, would require a bandwidth of well over 200 Mbps. A regular phone line for example, has a bandwidth of 56 Kbps, while a T1 line carries 1.5 Mbps of data. [Ref. 8] The large size of video files means that relatively broad bandwidth networks are needed

to transmit them. The goal of digital compression is to massively reduce the amount of data required to store and transmit a digital video file, while retaining its original quality.

The size of a video file depends on the bit rate and compression method used, so there is a tradeoff between bandwidth usage and video quality. The commercial efficiency of a compression method is based on playback rate, storage capacity, quality, and cost [Ref. 9]. Playback rates are the bit rates that a compressed file is transmitted across the network to the user. It affects the compression quality of the video. The higher the bandwidth, the better the quality. Of course, better quality translates into higher costs. Using an efficient digital video compression format can optimize the bandwidth usage and reduce costs.

F. COMPRESSION STANDARDS

Standards are important because they increase the availability of equipment and technologies which are interoperable within a given communication network. Industry accepted standards are rapidly replacing DoD proprietary development within the DII/COE. This section discusses the different digital compression standards in use today for bandwidth savings in a multicasting environment. The most widely accepted are MPEG-1, Indeo, and Cinepac[Ref. 9]. Cinepac and Indeo are CODECs (compression/decompression) solutions that compress video to 15 frames per second, which is half the frame rate of television. In addition to low frame rates, Indeo and Cinepac suffer from other major disadvantages. They are not real-time compression solutions. Which means that a user must download a file in its entirety before playing it back. In addition, they are not cross-platform. They can only be used on a computer and cannot be played back through set-top boxes for display on TV monitors. In short,

Cinepac and Indeo do not meet the quality standards or versatility needed for a robust digital production facility. MPEG-1 has been designed to overcome these limitations. [Ref. 9]

MPEG-1 is a digital video compression format that was defined by the Moving Pictures Experts Groups which is part of the International Standards Organization (ISO). MPEG-1 was developed by industry leaders to provide the best quality at playback rates of up to 30 frames per second at a bandwidth of 512Kbps. With a standard rule of thumb being 12.8 Kbits per frame MPEG-1 can provied near picture quality video at a transmission rate of 384kbps. [Ref. 14] This transmission rate is the baseline set for IT21 collaboration software[Ref. 16]. MPEG-1 compresses full screen full motion NTSC or PAL (30 or 25 frames per seconds) [Ref. 10]. Because it offers better quality, MPEG is suitable for a far broader range of applications than software only compression formats. One of the most important advantages of MPEG-1 is the fact that it is an official ISO standard. This means that MPEG digital video is can play back across different components and systems from different manufacturers or service providers adhering to the ISO standard. MPEG-1 can be played back on TV monitors, video CD players, CD-ROM drives and desktop computers [Ref. 9]. MPEG can be compared to VHS in its acceptance by the commercial sector as a standard.

Until MPEG was defined and recognized as an official standard, the full scope of desktop digital video was not realized. The reason for this is low quality and incompatibility of other so called standards. Although other digital video encoding formats exist, only MPEG delivers near-television quality, high compression ratios and standardized data transfer methods. MPEG compresses full screen full motion video,

which is 25 to 30 frames per second, whereas other software encoding compression formats usually only encode at about 15 frames per second. While these lower frame rates are acceptable, detailed uses such as telemedicine require higher quality.

Initially, MPEG required dedicated decompression hardware on the receivers desktop computer. In 1995, MPEG developed a software-only decompression solution that relieves some of the cost burden from the client machine [Ref. 10]. Now, operating systems such as Windows 95 and Macintosh include MPEG-1 software decompression capability as a standard [Ref. 10]. This means that CD quality sound and TV-like video capability is already available to most PC users. The prices of MPEG compression systems continue to fall and offer an ability to create in-house digital video content. The decreasing prices of MPEG compression systems and video authoring tools combined with multicasting's bandwidth savings make it a good choice for additional video services. The most widely accepted CODEC standards and their relative efficiencies are shown in Table 3. [Ref. 9]

CODEC	COMPRESSION RATIO	PLAYBACK RATE
MPEG-1	Up to 10,000 : 1	Up to 30 frames per second
CINEPAC	Up to 200 : 1	Up to 12 frames per second
INDEO	Up to 200 : 1	Up to 15 frames per second

Table 3 Compression Ratios

G. SUPPORTING HARDWARE

Hardware configuration and installation represents the largest portion of expense in constructing a multicast network [Ref. 17]. There are however an increasing number of vendors that are offering multicast capability as standard on new switching and routing

equipment. Vendors include Cisco Systems, 3 Com, Allaire, FORE, Ascend, and Hewlett-Packard. While the IP Multicast Protocol is an open standard, it is often necessary to have a homogenous suite of network equipment to ensure compatibility.

1. Server Requirements

A relatively robust server is needed for transmission and storage of multicast content. Server requirements vary according to the running application. In general, video on demand servers will require more storage capacity, while collaboration servers will require more memory and processing power. Table 4 lists the minimum server requirements for multicast services.

Component	Minimum
Central Processing Unit	200 MHz Pentium
Memory	256 MB
Hard Drive	4 GB
CD-ROM Drive	4X
Video Card	16 bit
Sound Card	16 bit
Operating System	Windows NT, 95, or 98

Table 4 Server Requirements [Ref. 17]

While this is a minimum listing, the described components can be acquired for much less than $1,000. A vendor's software application recommendations should always be followed to ensure adequate system performance.

2. Client Requirements

The client computer requirements are much less than that of the server. Some limited storage capacity is needed for video on demand services and resident applications (see Table 5). The majority of recent multicast applications are designed to be viewed through a standard Hyper Text Transfer Markup Language (HTML) Browser such as Internet Explorer or Netscape Navigator [Ref. 17].

Component	Minimum
Central Processing Unit	166 MHz Pentium
Memory	32 MB
Hard Drive	1.2 GB
CD-ROM Drive	4X
Video Card	16 bit
Sound Card	16 bit
Network Connection	Standard Ethernet or Dial-Up Modem
Operating System	Windows NT, 95, or 98
HTML Browser	Internet Explorer 4.0 or Netscape Navigator 4.5

Table 5 Client Requirements [Ref. 17]

3. Network Hardware

Hardware requirements include multicast-enabled switches and routers. These devices must have the capability to properly handle the protocols discussed earlier in this chapter. They must be able to process and transmit multicast packets over a local area network and between other multicast routers. Many vendors are building multicast capabilities into their current router and switch specifications. Table 6 lists the minimum protocol suites necessary for multicast-enabled network hardware.

Minimum Switch/Router Protocol Suite
Transmission Control Protocol (TCP)
Internet Protocol (IP)
User Datagram Protocol (UDP)
Real time Transport Protocol (RTP)
Real time Control Protocol (RCTP)
Real time Streaming Protocol (RTSP)

Table 6 Minimum Switch/Router Protocol Suite [Ref. 3]

4. Network Connectivity

The minimum requirement for local area connectivity is 10Mbps while wide area connections should allow a continuous 32kbps transmission capability [Ref. 5]. However, a multicast server/client infrastructure does not necessarily require a fixed local area or wide area connection. Client computers may use modems to connect to a wide

area network for multicast reception. The server should have at least a 32kbps connection to the wide area network while 384kbps is recommended for voice, video, and data interchange [Ref. 17].

H. SOFTWARE APPLICATIONS

In addition to multicasting hardware, a multicast-enabled software application must reside on the transmitting and receiving stations. Examples of such applications include Microsoft's NetShow, Cisco's Internet Protocol Television, VDOLive, and PointCast. Storage of multicast files requires significant hard disk space, with the actual size dependent upon several factors. As a guideline, files stored at a transmission rate of 1.2 Mbps rate will require about 540 MB/hour, and files stored at a 400 Kbps rate will require about 180 MB/hour. [Ref. 11] Chapter III presents a case study of various applications to include multicasting recorded video for analysis by small unit leaders training in a Military Operation in Urban Terrain (MOUT) facility.

I. SKILL REQUIREMENTS

Human Factors Engineering has been incorporated into a number of multicasting applications, and although the addition of new technology requires some initial increase in personnel, the management of multicasting can be accomplished fairly easily by most organizations' existing system administrators. For a price, the administrative burden can be assumed by an outsourced agency. Administrators will need the following skills; NT Networking Essentials, NT Server in the Enterprise, familiarity with the application of choice. The user will only need basic web viewing skills such as negotiating logons, Universal Resource Locators (URLs), and hyper-linked material. [Ref. 12]

The following chapter will focus on potential Marine Corps applications of multicasting. Most of the ideas presented stem from successful commercial implementation examples described in detail in Chapter IV.

III. MULTICASTING APPLICATION SCENARIOS IN THE UNITED STATES MARINE CORPS

Multicasting has a tremendous potential to increase the operational and administrative effectiveness of the Marine Corps. Borrowing from the previous chapter, we will look at Marine Corps specific mission objectives that may benefit from multicasting technology. To determine the best application potentials, these objectives must be properly analyzed. As stated in "United States Marine Corps Concepts and Issues 99" published by Headquarters Marine Corps, the Marine Corps acquisition focus is to leverage technological initiatives that improve mobility, flexibility, and lethality of our Marine Expeditionary Forces in a cost-effective manner. The scenarios discussed will be in support of the Marine Corps' primary warfighting doctrine, Operational Maneuver from the Sea (OMFTS) (see Figure 3-1). The concept combines advanced technology with maneuver warfare to dominate the littoral battlespace. [Ref. 1] OMFTS treats the coastal areas of the world as a single battlespace in which the coordination of sea, air, and land-based forces share a common picture of the mission, goals, strengths, and weaknesses of all friendly and enemy forces. A rapid decision cycle of Observation, Orientation, Decision, and Action, commonly referred to as an OODA loop (Figure 3-2), is essential to outpace the enemy and ensure our own forces are properly equipped and informed in an ever-changing hostile environment [Ref. 18]. The success of OMTFS hinges on effective:

- Ship to Objective Maneuver (STOM)
- Maritime Prepositioning Forces (MPF)
- Sustained Operations Ashore (SOA)

- Military Operations in Urban Terrain (MOUT)
- Seabased Logistics

While some of these seem to have very little to do with the communications, they are illustrative of the complex network of support the Marine Corps depends upon from both internal and external organizations. Each of these concepts can benefit from multicasting technologies tailored to support their unique objectives. The following scenarios provide a discussion of the benefits of multicasting technologies in support of OMTFS.

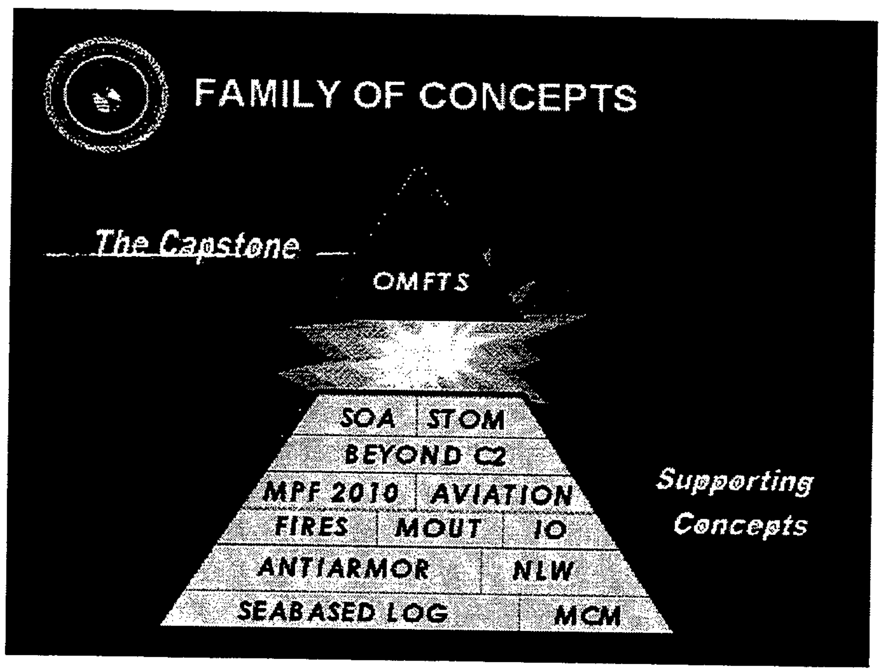


Figure 3-1 Operational Maneuver From The Sea [Ref. 1]

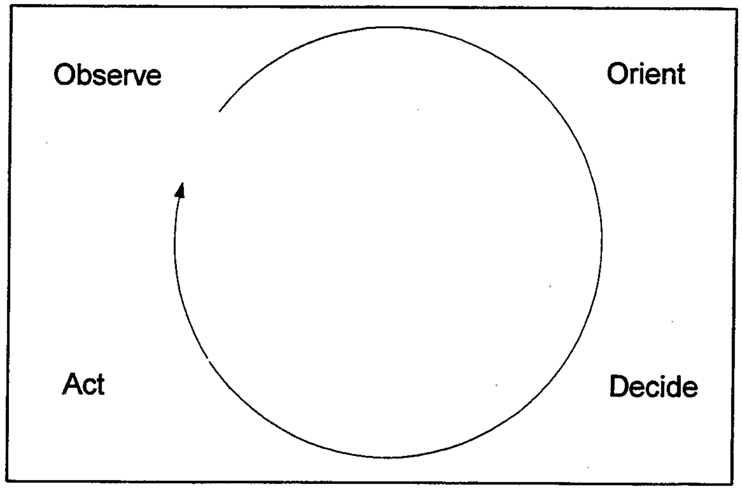


Figure 3-2 Boyd's OODA Loop [Ref. 18]

A. SHIP TO OBJECTIVE MANEUVER (STOM)

The concept of ship to shore movement is replaced in OMFTS with STOM. As the addressed in Chapter I, the securing of a beachhead is not always essential to winning an engagement. In STOM, operations will begin from over the horizon and project power deeper inland than in the past, progressing with speed and flexibility of maneuver that will deny the enemy time to react. Forces will move to engage the enemy without the previously doctrinal establishment of a static defense position along the beach. This type of engagement is made possible not only by advanced lift capabilities, such as the Advanced Amphibious Assault Vehicle and the V-22 Osprey, but also by a robust command and coordination network. [Ref. 1] (The term "coordination" has replaced the more familiar "command" as the total battlespace must be synchronized among numerous naval, ground, and supporting forces and not just the commander of the landing force.) [Ref. 1] Commanders will have to ensure their higher, adjacent, and subordinate units are informed of his or her objectives and intent. While under the best of circumstance the commander communicates in person, physical and temporal dispersion within a sea-

based environment often reduce communications to video teleconferencing, voice, or at worst message traffic. Marines conducting operational maneuver from the sea will strike from U.S. Navy amphibious ships. These ships provide operating platforms for landing craft and aircraft, command and control systems, berthing, staff accommodations, weapons suites, and damage control in addition to moving forces to the area of operation. Such characteristics allow for the transportation, projection ashore, support, recovery, and redeployment of Marine Air Ground Task Forces (MAGTF). The information volume required to make this happen is staggering. Bandwidth is at a premium as everything from weather updates to logistics and intelligence information must be funneled through the ship's communication suite. This is often to the detriment of the MAGTF planning cell. Bandwidth is not reserved but maximized to meet the current needs of the ship. Through no fault of the Navy, communication bandwidth priorities usually lie with the ships vital command, control, and safety links [Ref. 15]. To facilitate a VTC session, other communication services are degraded to include voice and data. The 384 Kbits needed to carry a VTC session must be taken from some other communication application's bandwidth (see Figure 3-3). Because of their impact, VTC sessions must be planned for and executed within a given time frame. [Ref. 15] Figure 3-3 shows the IT21 bandwidth requirement for a Naval Expeditionary Force (NEF) which would include an Amphibious Readiness Group (ARG) carrying Marine forces.

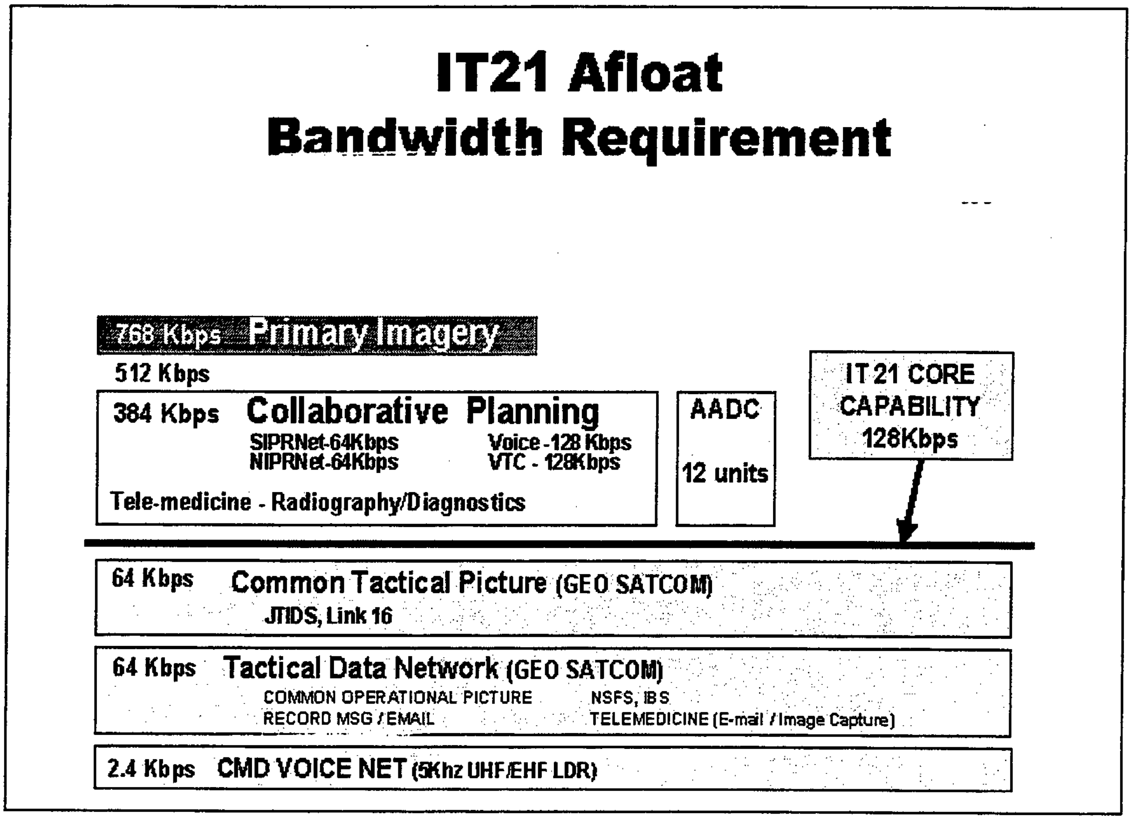


Figure 3-3 IT21 Naval Bandwidth Requirements [Ref. 21]

A collaborative planning session shown in the above figure requires a minimum of 384 Kbps of bandwidth. This collaborative session assumes voice, video, and a whiteboard or mapping application. As illustrated in Chapter II, if the 384 Kbps were used solely for video, it could provide a 30 frames per second (fps) video stream (each frame per second requires approximately 12.8 Kbps). The addition of voice and accompanying application push the frame rate down to around 15 fps. Under unicasting the allocated 384 Kbits only supports one collaborative session. [Ref. 15] This means only two ships can share the same information within a given session. While multicasting will not provide any significant advantage in point to point communications, it has been shown to allow the same 384 Kbits bandwidth to provide up to nine simultaneous usable collaboration sessions [Ref. 15]. This would give a MAGTF commander the ability to exchange information with nearly all of his subordinates who

may be distributed throughout several ships within the NEF. The alternative to this process usually requires physical transportation of personnel between ships; a costly, time consuming, and potentially hazardous method of planning. With a rapid response planning cycle for reacting to orders limited to six hours, a commander cannot afford to lose valuable time coordinating transportation for key staff planners. Also, with bandwidth at a premium, multicasting allows greater connectivity without impacting the quality of other communication services. While 384 Kbits is still taken out of service, no additional bandwidth overhead is created with the addition of multicast recipients.

B. COMMON TACTICAL PICTURE (CTP)

Along with maximizing bandwidth usage, multicasting provides a common tactical picture (CTP) of force employment and commander's intent to a greater audience. The CTP is defined as the current anticipated, projected, and planned disposition of forces that includes amplifying data for a single operation. Real time, near real time, and non-real time data from national, theater, and tactical sensors feeds the CTP via available communications links provided by the Service Components and other organizations. For each new operation in a Commander In Chief's (CINC's) theater, a new CTP will be created and managed. A CTP is built around the need for situational awareness from the highest command to the lowest organizational levels. [Ref. 19] Improved situational awareness enables faster and more informed OODA Loops. A key element of awareness is the commander's ability to understand his own strengths and weaknesses and react to them before the enemy can exploit them. This is even more crucial when determining force sustainment capabilities which impact a commander's decision to commit or withdraw forces. This ability to simultaneously deliver information

to a specific group of users would also benefit the requirement of the GCE to coordinate the simultaneous employment of numerous and widely distributed maneuver forces. Current capabilities exist to multicast down to the Regimental level through organic microwave transmission assets such as the MRC-142. Although these units currently have well structured Combat Operations Centers (COCs), they would only gain a true CTP through a medium that delivers real time multiple and simultaneous updates. This is especially critical for high valued information such as supporting fires and the Air Tasking Order (ATO) where units are usually prioritized in the receipt of the of the data. Again, synchronization of situational awareness can aid the commander in ensuring his subordinate commanders have every available piece of information that could enhance their combat effectiveness. Multicasting would allow quick responses to exploitation opportunities or changes in the battlespace. With better situational awareness, subordinate commanders could better utilize their assets to request fires, intelligence support, or resupply. Another bandwidth intensive application is the transmission of intelligence imagery. In order to achieve and maintain situational awareness, anticipate taskings, and rapidly respond to assigned missions, the MAGTF commander must have full connectivity with the joint intelligence architecture and be able to request, receive, and utilize intelligence products in real time. The example of the Promus Corporation (see Chapter IV) can be used as a model to show the tremendous time saving involved in used in imagery. Software updates that once took days for Promus to distribute to its more than 1,300 hotels, now take minutes because the transmitting station does not have to duplicate the original transmission information. Similar use of multicasting for sending

imagery will allow commanders to push information down to their subordinates while reducing the impact on critical combat communications resources.

C. MARITME PREPOSITIONING (MPF) AND SEABASED LOGISTICS

The concepts of seabased logistics, MPF, and sustainment ashore rely on ships of the amphibious task force and MPF to serve as floating combat service support platforms to resupply the ground units rapidly and directly, fully exploiting the lift and mobility offered by landing craft and air assets. By seabasing most supporting fires, landing force vulnerability and footprint ashore are significantly reduced, greatly improving the Ground Combat Element's (GCE) ability to maneuver. [Ref. 1] Although maneuver is gained, commanders will still depend on the reliability of logistical information to make critical force employment decisions. As will be discussed in the following chapter, Schlumberger Petroleum installed a multicast application that could monitor key critical changes in production or distribution of their product. Remote monitoring stations transmitted small amounts of data (below 28 Kbps) simultaneously to distributed locations throughout the world, making essential information about each facility available to all key decision makers. They could see how delays or increases in production would impact their own mission objectives. Schlumberger then used this information to adjust their capacities or operations to benefit production or at least sustain minimal impact. Similarly, the GCE commander who is dependent on seabased logistics, and eventually sustainment ashore, could benefit from multicasting applications. Although the commander will not be burdened with a large physical logistics train, he will still have to make critical decisions based on his awareness of his sustainment and resupply capabilities. The Marine Corps can benefit greatly from Schlumberger's example. While

the company's multicasting application may not seem necessary with such a low volume of data, it is the "simultaneously" that is the key word. In unicast delivery, a replicated message is received by the user in the order that it was sent. If the user is the 100th recipient, his data will not be transmitted until after that of the 99th recipient. Although delays may be minimal on an intranet (less than 1/100msec), unicasting delays combined with the latency of the Internet can cause very desperate time differences [Ref. 8]. With multicasting, the data will be received at all locations at relatively the same time (plus latency of the network.) [Ref. 3] This is crucial when updating databases containing logistic or personnel information that commanders will base force employment decisions upon. Supply organizations which would include not only maritime prepositioning ships, but also aviation logistics support ships, hospital ships, and offshore petroleum distribution systems could host remote monitoring applications that recorded stockage levels of combat essential items or readiness levels of essential services. This information could be multicast to all commanders who required the information. They would see the same information at the same time. Again, the need for a common tactical picture in real time could be realized. Commanders could gain a sense of confidence in the accuracy of synchronized supply and support databases that include information on food, ammunition, and personnel levels knowing that they are seeing the same information as their higher, adjacent, and subordinate units.

D. MILITARY OPERATIONS IN URBAN TERRAIN

As the world continues to urbanize, Marine forces will have an increasingly necessary role in Military Operations in Urban Terrain (MOUT). According to United Nations estimates, the urban population of developing countries worldwide increases by

about 150,000 people each day, with the most pronounced growth occurring in Africa and Asia. By the year 2025, three-fifths of the world's population will live in urban environments. [Ref. 1] The need to operate in situations where the enemy is hidden amongst the indigenous population will require enhancements in training, command and control, intelligence, and small unit leadership. Urban terrain pushes command and control to the very limit. The changing structures and lack of sufficient intelligence detail puts a special emphasis on the small unit leader. He will most likely be physically and situationaly separated from higher and adjacent units. His ability to make accurate, timely decisions will be the key to combat effectiveness in urban environments. [Ref. 1] While multicasting is not currently available to support these units in the actual tactical environment, Chapter IV shows how the Army is using it to aid the development of small unit leaders. It is often difficult to give leaders an adequate evaluation of their own effectiveness. They are usually involved in the training to an extent that they cannot be everywhere at once to evaluate their team and also relies on second hand evaluation of their own leadership skills. The McKenna range solution of recording video and archiving it on disk can be equally valuable to Marine Corps MOUT facilities. Like their Army counterparts, Marine NCOs and officers could log on to a desktop computer connected to an on-demand video server to review their actions after the MOUT exercise. With the use of multicasting applications, the user would only need basic web browsing skills to find his particular MOUT data file and then be able to play, pause, and review the video at his own learning pace. The multicasting reduces the burden on the network and allows as many users as possible to review and assess their training experience. This application carries over into numerous other Marine training scenarios. The MPEG-1

video standard discussed in Chapter II can be used to cheaply and efficiently record exercise and training scenarios at a high fidelity for future storage and playback. Information can be stored digitally on a hard drive or compact disc with reduced requirement for degradable media such as VHS tapes with a limited storage life. The digital information can be transferred to any compatible server and multicast to any number of recipients. [Ref. 13] The next chapter will discuss examples of organizations that have successfully implemented multicasting technology. While most of these are commercial, they are easily translated into the previously discussed Marine Corps applications.

IV. MULTICAST DEPLOYMENT CASE STUDIES

Understanding a system is often incomplete without doing case studies of a few successful implementations. The knowledge and lessons learned through other organizations' experiences can help the Marine Corps better determine its need for these new technologies. This portion of the paper examines the successful deployment of multicasting applications within several different organizations.

A. US ARMY MOUT FACILITY ON-DEMAND AFTER ACTION REVIEW

1. Problem

Located at Fort Benning, Georgia, the Army's Ranger School trains thousands of soldiers per year. Its mission is to teach and develop Combat Arms Functional Skills relevant to fighting the close combat, direct fire battle. It provides practical experience in the application of the tactics and techniques of small unit operations in wooded, mountainous, and urban environments. The course is 61 days in length with an average of 19.6 hours of training each day, seven days a week. The emphasis during the course is on practical, realistic, and strenuous field training. Its Military Operations in Urban Terrain (MOUT) training facility is used to simulate urban combat conditions. The facility is comprised of 31 buildings (two support helicopter landings), 120 feet of tunnel system, and scenario damaged buildings. A typical MOUT exercise could simulate hostage rescue, house clearing, or riot control. Although the MOUT facility provides an excellent training experience, its physical structure of multi-level office buildings and houses limit instructors' ability to adequately monitor training. The Army needed a way to adequately monitor and analyze both individual and unit skill levels within the MOUT

facility. Even with additional instructors, it was difficult to provide an after action brief to the unit commanders who participated in the MOUT training.

2. Solution

With the desire to provide better training analysis and feedback, the Army installed a digital video monitoring and archiving system. This system allows a single operator to record simultaneously 40 or more video inputs from cameras located throughout the MOUT facility (see Figure 4-1). Cameras were installed in all of the facility's buildings and outside structures to provide instructors with the ability to monitor all activity during an exercise. Capabilities of the MOUT Instrumentation System (IS) include: visual day/night cameras; two-way and tactical communication audio coverage; time tagging of all recorded events in real time; soldier identification; soldier location (x, y, z coordinates); opposing forces (OPFOR) location; target location; weapons effects (what fired, when, what effects); OPFOR/target results; fratricide recording; and the ability to visually represent and electronically replicate collected data for post experiment analysis. Supporting IS sensors include acoustic, IR, laser, seismic, GPS, and video. Throughout an exercise, activity is monitored from the MOUT's control center. Once an exercise has been completed, the recorded files are automatically indexed and saved to disk. Training events are stored as digital video files (MPEG1) and can be played back simultaneously for instant "after action review" (AAR). With multicasting, the large file sizes associated with video present no significant load on the facility's local area network. The archived videos are transmitted once and viewed at any number of desktops throughout the training facility. The files can also be searched and reviewed for analysis at any later date

from a users desktop computer. The volume of stored data is kept to a minimum through real time editing by instructors and deletion after review by the individual or command. [Ref. 13]

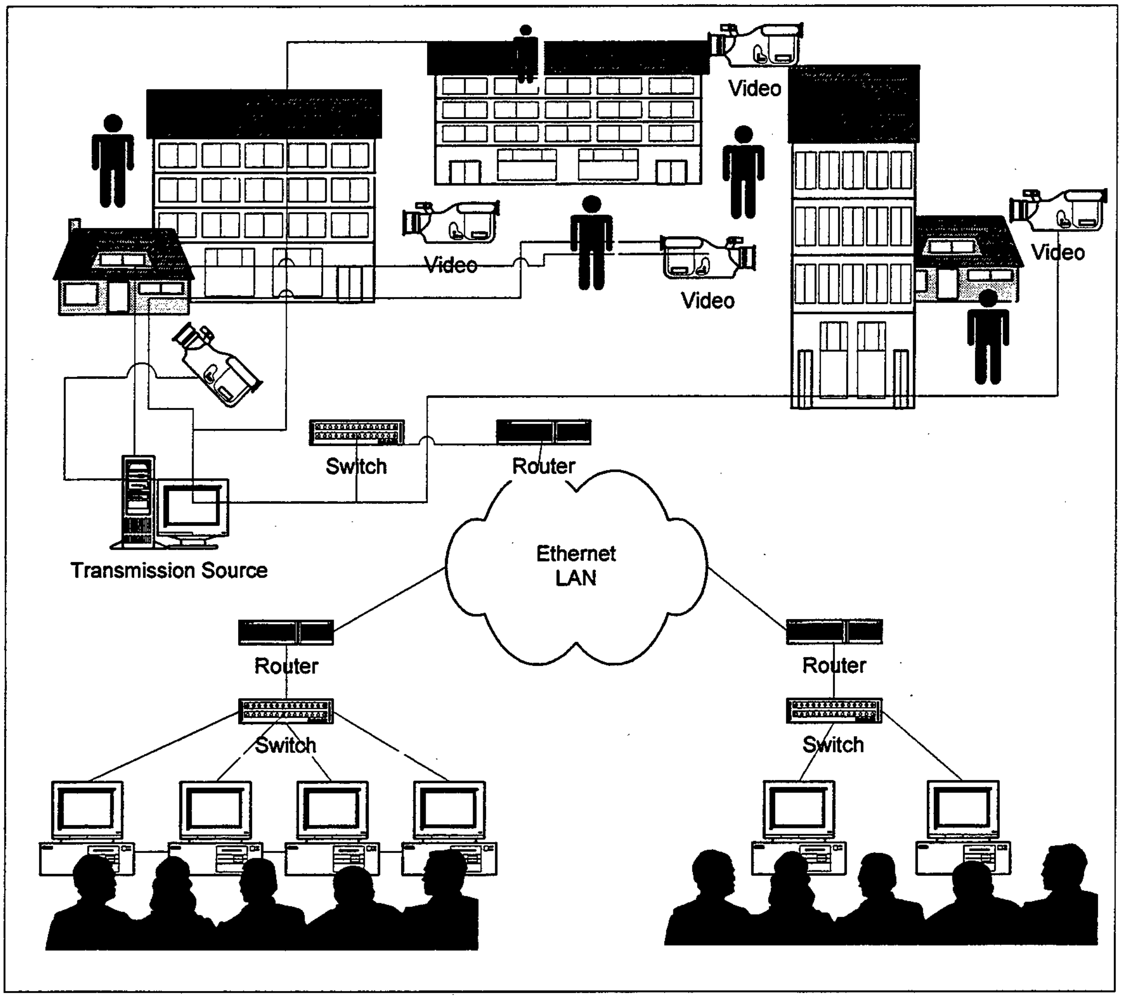


Figure 4-1 Army MOUT Facility

3. Benefits

Using their web-browsers, authorized users on the local area network can search the video database for specific files and then play these files directly from the server to their desktop PC' s. They do not need to request a copy of the video or download the video file to their desktop machine. Digital video files can easily be edited and then

distributed to the trainees and participants in an exercise via CD-ROM or attached to an e-mail. The following quote is from the Senior Systems Analyst at the Army's Dismounted Battlespace Battle Lab: "The digital storage and retrieval system ... developed and installed for our training and experimentation range at Fort Benning, GA, has proven to be of immeasurable value. With this instant playback capability, training forces are able to execute a training scenario and review all the recorded video in detail, just moments later. Being able to immediately identify their mistakes, they are then able to take corrective actions and greatly enhance the benefits of their training time." [Ref.13]

The Army feels that this is a tremendous success. The benefits of this implementation include a reduced requirement for monitor personnel and the ability to review training on-demand with commanders and participants. The Army spent less than $25,000 on equipment and $2,000 for the software site license plus $100 per user. The Army plans to extend the number of licenses and wants to enable the multicasting capabilities over a wide area network. [Ref.13]

B. MICROSOFT DEVELOPER'S NETWORK

1. Problem

Microsoft has more than 30,000 employees located at its headquarters in Redmond, Washington. Rapid product development, testing, and deployment are central to the company's success. As its product line became larger and more complex, it needed a way for engineers and developers to collaborate and receive information without taking them out of the production cycle. Development meetings would require physical

attendance and would take personnel away from the critical development process. [Ref. 12]

2. Solution

The company installed a multicast-enabled network capable of simultaneously sending data to all of its 30,000 employees (see Figure 4-2). The network is used to transmit live and recorded audio and video content. Their multimedia programming includes three radio stations and a live MSNBC television channel feed. Additional channels are available on an as needed basis to carry live coverage of corporate events and corporate communications [Ref. 12]. Critical content is archived on disk for user defined on-demand viewing. Developers can attend virtual planning sessions or listen to other information critical to their development product.

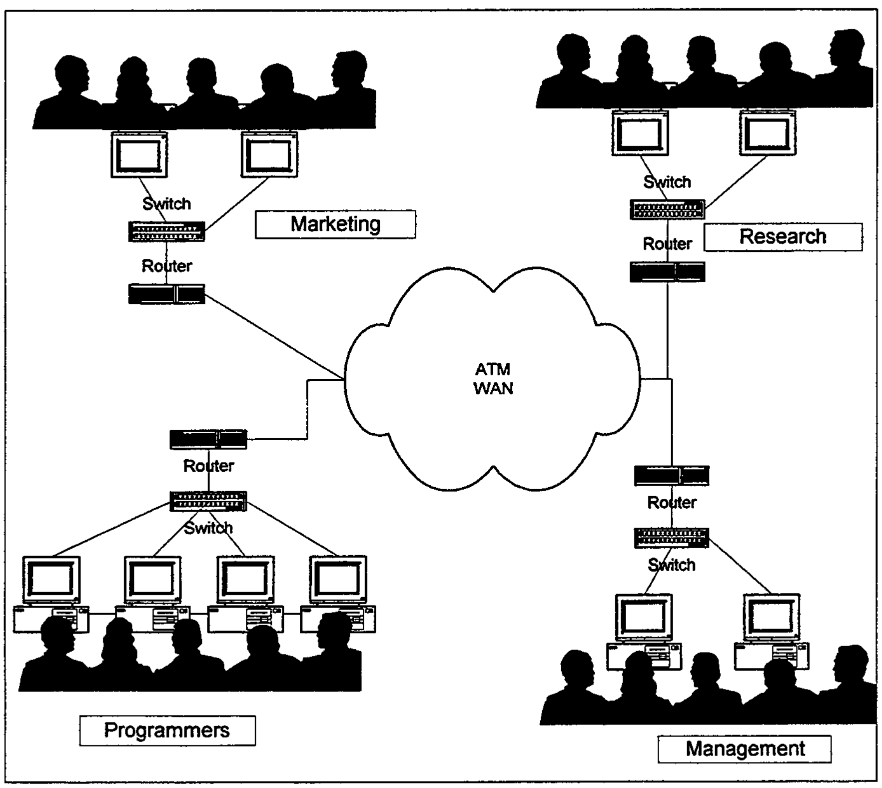


Figure 4-2 Microsoft Developer's Network

3. Benefits

By multicasting just one major company meeting, Microsoft avoided the costs of renting a facility and transporting more than 5,000 employees from the corporate headquarters. Microsoft also realized significant productivity savings because many workers took advantage of the on-demand viewing option to minimize disruption of their work schedules. Another less tangible benefit of the multicast network is the improvement in the quality of corporate communications because all employees can now be included in important corporate messages for a very low marginal cost. The company's founder and CEO, Bill Gates, is very excited about the potentials of multicasting and dedicates a section to it in his new book Business at the Speed of Thought [Ref. 24]. Microsoft plans to extend multicast video coverage of corporate events to all its sites in North America. [Ref. 12]

C. GENERAL MOTORS INFORMATION DISTRIBUTION NETWORK

1. Problem

General Motors needed to ensure its 8,500 dealerships received key information in a timely manner. Traditional methods of data distribution such as mailing disks and point-to-point transfers took weeks, and could not guarantee all dealerships received business-critical information simultaneously. Sales people had trouble finding the specific cars their customers wanted, and that put sales in jeopardy. Service people had to keep vehicles in the shop longer when they didn't have up-to-date service instructions. GM's old data distribution system caused most of the problems. Information, such as car pricing and availability, dealer incentives, and service bulletins, was sent point-to-point to each dealership, or copied to diskettes and CD-ROMs and overnight mailed. Information

sometimes took weeks to get to dealerships, and even longer to get to employees as non-technical dealers tried to install it on their computer systems. [Ref. 14]

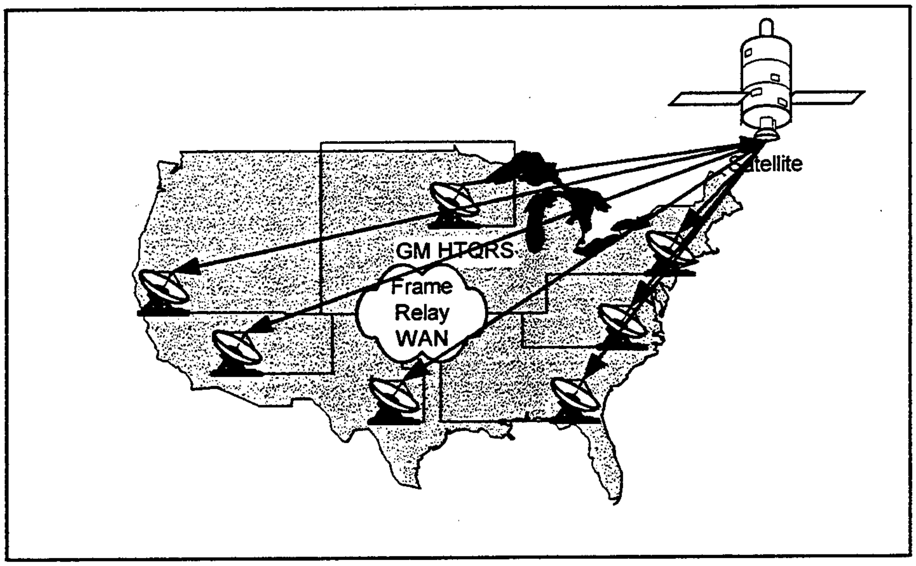


Figure 4-3 GM Information Distribution Network

2. Solution

GM began distributing information and software updates over its existing satellite network via multicasting (see Figure 4-3). This ensures every dealership receives the information it needs at a lower cost of distribution. Where it once took 30 minutes to send a 1Mbyte file to a limited number of dealerships, GM can now send the same file to more than 500 dealers in under three minutes. [Ref. 14]

3. Benefits

GM used its existing satellite network with no required modifications to transmission equipment. In addition to reduced satellite usage costs, management can now verify that data has arrived at each dealership in its entirety. If a portion of data is lost or corrupted, it can be retransmitted to that particular dealership. "To provide the best service possible, every dealership employee needs immediate access to the most up-to-

date information available. Timely information is vital. Why waste a week looking for a part when you can find it in a few minutes?" says GM's Information Technology Program Manger Wayne Stein. GM dealerships receive information efficiently and reliably, allowing them to provide their customers with up to date information. Dealers can now devote their time to sales and service rather than administrative tasks. This translates into more opportunities to close sales. [Ref. 14]

D. PROMUS CORPORATION SOFTWARE DISTRIBUTION NETWORK

1. Problem

The Promus Corporation owns Embassy Suites, Hampton Inns, and Homewood Suites chain which includes over 1,300 hotels on two continents. All the hotels use the same software to run their front desk check in/check out, room rates, and housekeeping systems, and are also equipped with a complete suite of Microsoft Office software. Keeping all of this software up-to-date with periodic upgrades cost Promus up to $1 million per year through a time-consuming process of duplicating diskettes and shipping them to each hotel. When the diskette arrived at each hotel, an employee on site was pulled off their regular duties to install the software while an engineer coached them through the process. Often, an engineer would have to be flown on-site to properly update the software. Software updates would sometimes take up to three years to reach every hotel. Even with the company's satellite network, unicasting a software upgrade of 30 Mbytes would take half an hour to deliver data to one site and over 50 hours of continuous transmission to reach 100 of the 1,300 sites. In addition to the time requirements, all other traffic on the network would have been degraded. [Ref. 14]

2. Solution

Promus had an existing Very Small Aperture Terminal (VSAT) network used for the transmission of accounting and occupancy data. By deploying multicast software on this network, Promus can perform simultaneous software upgrades to all 1,300 hotels at a fraction of the time and at a cost savings of nearly 90% (see Figure 4-4). After the initial investment of buying and deploying the multicast software applications and configuring the network, the cost of software upgrades dropped to approximately $200 per year per hotel. Mailing cost and personnel travel costs were also eliminated. Software maintenance and help-desk operations are also more efficient because all of the hotels are updated with the same software at the same time. Help-desk personnel only have to have knowledge of one software version. [Ref. 14]

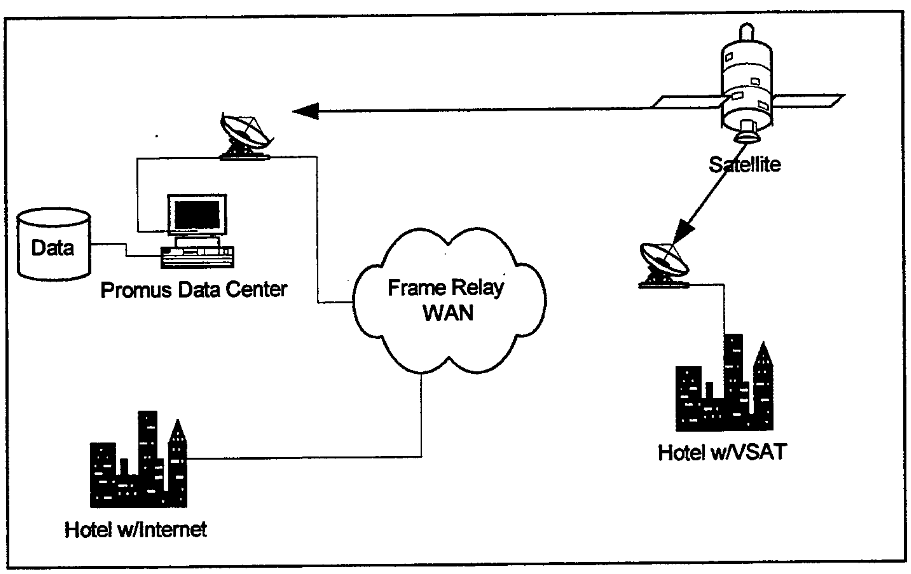


Figure 4-4 Promus Software Distribution Network

3. Benefits

Each hotel property has a local Windows NT Server-based server running Pentium Pro processors and up to 10 gigabytes of disk storage. Promus also has PCs wherever in the hotel they need them: front desk, housekeeping, accounting, manager's office. Each server is linked to headquarters over a VSAT network that provides a 512 kbps downlink to the hotel and a 56 Kbps uplink. The central customer database, which contains approximately 30 million records, is updated every night, allowing management to gain instant utilization feedback. Using multicasting, Promus can upgrade software at any property for less than 3 percent of the $2,000 it cost the old way. The company can install and test new software and remove old software, all from corporate headquarters, in about five minutes. Training costs, for example, have dropped from approximately $11,000 to $3,000 per employee. Instead of sending new staff to formal training at its corporate headquarters, Promus now trains them via multicast classes locally. Promus' software upgrading costs have dropped from $1 million to less than three thousand dollars per year. Personnel costs have also dropped due to a reduced need for software support engineers. They also plan to introduce on-demand video services deliverable to each hotel room. [Ref. 14]

E. SCHLUMBERGER-DOWELL REMOTE MONITORING NETWORK

1. Problem

Schlumberger Oilfield Services provides exploration and production services to the petroleum industry. They specialize in offshore oil platforms and have over 100 remote offices around the world. Annual revenues in 1997 totaled $10.65 billion.

Because production, distribution, and consumption of oil are interconnected, any equipment failures or delays in one location spill over to the other areas. Schlumberger lost on average $16 million per year due to disruptions in production and distribution. Most of the costs were associated with delays in relaying information about equipment failures in a timely enough manner for other locations to react accordingly. Many of the company's employees were in remote locations with low speed dial-up connections. Schlumberger's first attempt to distribute information was through e-mail. This meant coordinating, generating, and transmitting e-mails to over 5, 000 employees. This method put an extreme burden on the company's network and did not produce any positive increase in situational awareness. E-mail has to be checked for and read by the user. There are a limited number of ways to verify that the e-mail has been received and read by the right people. [Ref. 20]

2. Solution

The company developed an application that automatically distributes simultaneous failure updates, maintenance schedules, and operational alerts targeted to specific employees worldwide (see Figure 4-5). The application is delivered via multicast and does not place an undue burden on the network. Management software is used to ensure that only available bandwidth is used and no user applications are degraded. Employees can continue working without being interrupted, unaware that the information is streaming down to their desktop computer. As important information is received, users are automatically alerted through flashing screens and audible tones. They can see in real-time the status of any production or distribution facility within the corporation. [Ref. 20]

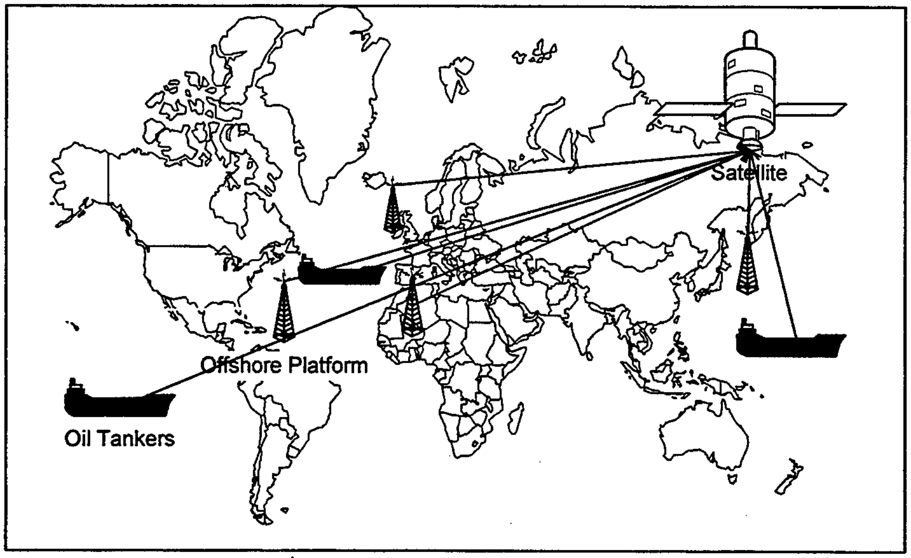


Figure 4-5 Shlumberger-Dowell Remote Monitoring Network

3. Benefits

Based on past year losses, Schlumberger anticipates the reduction in failures and downtime to translate into a savings of more than $8 million per year. The company also expects revenues to increase in response to an enhanced ability to monitor equipment, production, and personnel. "The competitiveness of the petroleum industry demands instant reaction to changing conditions…multicasting allows us that option" states Schlumberger's Chief Information Officer. [Ref. 20]

F. SUMMARY

Since implementing multicasting, all of these organizations have benefited from time, equipment, and personnel cost savings. Multicast has proved to be a very efficient way to deliver data in a timely manner at a low cost per user. The next chapter will summarize the real and potential benefits of multicasting applications.

V. MULTICASTING'S BENEFIT TO CURRENT MARINE CORPS OBJECTIVES

A. INTRODUCTION

Multicasting has the power to transform the way the Marine Corps operates. It allows the best utilization of network assets to include the capability to efficiently collaborate and distribute critical information. The following is a discussion and non-inclusive list of the many benefits multicasting offers.

B. DISCUSSION

Aside from using multicast technology to help fewer personnel operate major systems, thus making the assigned personnel inherently more productive, multicasting can be applied to speed training and improve job performance, through such activities as training in synthetic environments and using distributed simulators to represent newly introduced equipment or procedures, thereby shortening the time required for more expensive training with actual systems and forces in their real environment. Multicast networks and their associated software applications allow distributed training, so that one expert instructor can train people simultaneously at widely dispersed locations, with a resulting reduction in travel costs and time away from primary duties. On-demand viewing through multicasting will allow each trainee to go at his or her own pace, without having to conform to a fixed schedule based on some average training performance; it will also be possible to easily change the courseware to fit the different backgrounds of trainees and different circumstances of training and variations in network architecture. Multicast networks will also provide greater access to remotely located experts once unavailable or limited due to time, space, or monetary constraints (Figure 5-1) [Ref. 17].

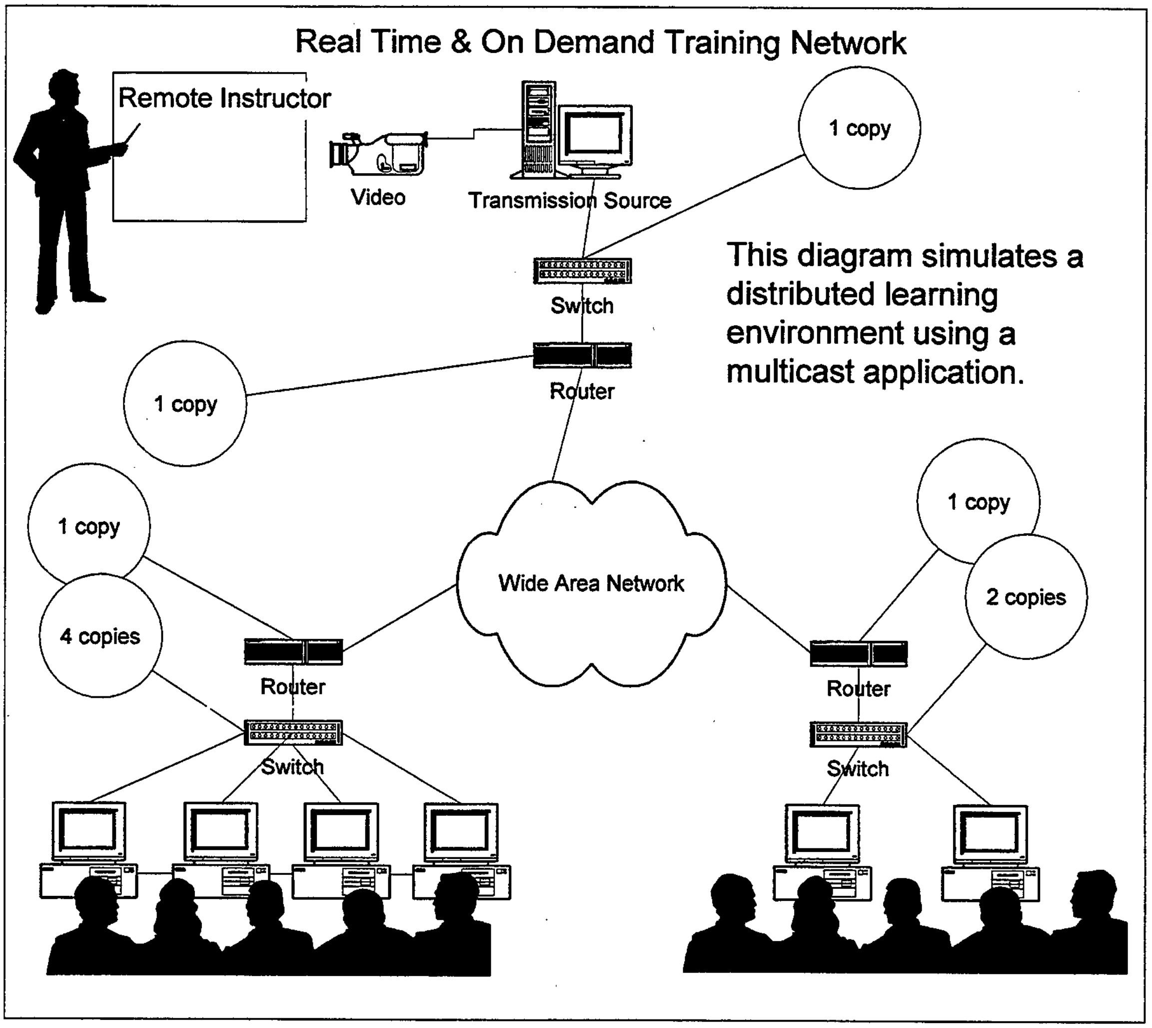


Figure 5-1 Multicast Training Network [Ref. 6]

Multicasting delivers real time and archived materials, including audio and video, directly to the individual user's desktop. In addition, live content can be archived to disk for subsequent on-demand viewing. This allows information synthesis to occur whenever the user has available time, without the need to allocate additional network bandwidth or tie up limited VTC facilities. It also means that training can be conducted at a reduced cost. Training and communication can be done online, at any time of the day, at prices

far below those offered by conventional means of resident and non-resident Military Occupational Specialty (MOS) schools and Professional Military Education (PME).

Current expenditures on analog Video Teleconferencing (VTC) facilities exceed $1,000 per seat in addition to monthly line or satellite access charges. The number of seats is also limited by the physical constraints of the VTC facility. [Ref. 5] Emerging software applications that exploit the multicasting protocol can reduce the price per user far below that of conventional collaborative applications in addition to reducing manpower costs associated with VTC administration. Uunet Technologies Inc., owned by MCI, currently offers a 25 Kbps data stream (which is suitable for the transmission of voice and video at 15 frames per second) for $11,000 per month, and can send that 25 Kbps stream to 250,000 users simultaneously. A similar unicast data stream would require more than 65 T3 (45 Mbps) connections and if used for the entire month would cost over $3 million. [Ref. 6] A substantial savings for multicasting.

Any form of network communication involving the transmission of information to multiple recipients can benefit from the bandwidth efficiency inherent in multicast technology. Examples of applications involving one-to-many or many-to-many communications include: video and audio broadcasts, videoconferencing/collaboration, live news feeds, database updates, imagery dissemination, and software distribution. Multicast can run over almost any network infrastructure including dial-up modems, Ethernet, Digital Subscriber Line (DSL), Asynchronous Transfer Mode (ATM), microwave, and satellite [Ref. 7]. In addition, a list of multicasting's innumerable benefits is presented below.

C. BENEFITS

1. Multicasting is an optimum and cost effective method of delivering live or archived information to group of preselected individuals while avoiding the replication costs of unicasting and the indescriminance of broadcasting.
2. The current IT21 specified equipment (the Windows NT operating system) has built-in multicasting capabilities. In addition multicasting functions within the parameters of the OSI 7 Layer model and most major vendors, to include Cisco Systems and 3Com, include multicasting capabilities as a standard option on their routers avoiding the cost of additional upgrade requirements.
3. The recipient's desktop computer requires little special hardware or software besides the standard Web browser, avoiding the cost of additional upgrade requirements.
4. Multicast networks and their associated software applications allow distributed training, so that one expert instructor can simultaneously train people at widely dispersed locations, with a resulting reduction in travel costs and time away from primary duties.
5. Multicast networks will also provide greater access to remotely located experts once unavailable or limited due to time, space, or monetary constraints. The access includes videoconferencing/collaboration, live news feeds, database updates, imagery dissemination, and software distribution.
6. A host has a dynamic membership, meaning people can join or leave the group at any time. Members of a host group are also able to be members of other groups simultaneously thus increasing information fusion.

7. Registration and management is coordinated through the multicast application's software. This means there is no network-associated learning curve involved with being a user of the multicast application. In fact most application interfaces are very similar to Internet web pages with point and click hyperlinks.
8. Multicasting allows interactivity between the sender and recipient to include text based messaging to augment a live presentation or, with a properly constructed interface,VCR-style controls such as pause, fast-forward, and reverse for a previously recorded video or audio stream.
9. High bandwidth microwave links exist within the Marine Corps at the Marine Expeditionary Force level for communication to higher, adjacent, and supporting units. The Marine Corps has low-bandwidth (less than 32kbps) microwave assets distributed down to the regimental level. While these are not currently capable of handling high volume data, multicasting can maximize their throughput.
10. Tactical and strategic satellite receiver assets exist at almost every level within the Marine Corps. Again, satellite transmission is ideal for multicasting because of its greater effective coverage area. Since it costs as much to send to a single site as it does to many, so the larger the network, the more likely that satellite will be the best alternative. It is also ideal for tactical employment as its infrastructure is already existent within the Marine Corps command and control architecture. In the near future, with the advent of new, low earth orbit (LEO) satellite services, worldwide, ubiquitous multicasting is more than a reality.
11. As seen in the Microsoft example, multicasting can reduce the product development, testing, and deployment cycle. By multicasting, Microsoft avoided the costs of

renting a facility and transporting more than 5,000 employees from the corporate headquarters. Microsoft also realized significant productivity savings because many workers took advantage of the on-demand viewing option to minimize disruption of their work schedules. Another less tangible benefit of the multicast network is the improvement in the quality of corporate communications because all employees can now be included in important corporate messages for a very low marginal cost. The Marine Corps could gain similar benefits in collaboration.

12. Administrators can verify that data has arrived at each user site in its entirety. If a portion of data was lost or corrupted, it can be retransmitted to that particular site.
13. Automatic distribution of simultaneous logistic updates, maintenance schedules, and operational alerts targeted to specific personnel worldwide.
14. An enhanced ability to monitor equipment, production, and personnel in real time
15. Allows a MAGTF commander the ability to exchange information with nearly all of his subordinates who may be distributed throughout several ships within the NEF.
16. Remote monitoring stations transmitting small amounts of data (below 28 Kbps) simultaneously to distributed locations throughout the world making essential information about each unit available to all key decision makers. They could see how delays or increases in operations would impact their own mission objectives. This is crucial when updating databases containing logistic or personnel information that commanders will base force employment decisions upon. Supply organizations which would include not only maritime prepositioning ships, but also aviation logistics support ships, hospital ships, and offshore petroleum distribution systems, could host remote monitoring applications that recorded stockage levels of combat

essential items or readiness levels of essential services. This information could be multicast to all commanders who required the information. They would see the same information at the same time. Again, the need for a common tactical picture in real time could be realized. Commanders could gain a sense of confidence in the accuracy of synchronized supply and support databases that include information on food, ammunition, and personnel levels knowing that they are seeing the same information as their higher, adjacent, and subordinate units.

17. This ability to simultaneously deliver information to a specific group of users would also benefit the requirement of the GCE to coordinate the simultaneous employment of numerous and widely distributed maneuver forces. Current capabilities exist to multicast down to the Regimental level through organic microwave transmission assets such as the MRC-142. As discussed in Chapter III, other communications capabilities will have to share the available bandwidth resources. However, bandwidth is so precious at the tactical level, that a major shift in how information is delivered will be required. Although these units currently have well structured Combat Operations Centers (COCs), they would only gain a true Common Tactical Picture through a medium that delivers real time multiple and simultaneous updates. This is especially critical for high valued information such as supporting fires and the Air Tasking Order (ATO) where units are usually prioritized in the receipt of the of the data. Again synchronization of situational awareness can aid the commander in ensuring his subordinate commanders have every available piece of information that could enhance their combat effectiveness. Multicasting would allow quick responses to exploitation opportunities or changes in the battlespace. With better situational

awareness, subordinate commanders could better utilize their assets to request fires, intelligence support, or resupply.

18. Help achieve and maintain situational awareness, anticipate taskings, and rapidly respond to orders.

19. Marines can log on to a desktop computer connected to an on-demand video server to review training material. With the use of multicasting applications the user would only need basic web browsing skills to find his particular lesson file and then be able to play, pause, and review the video at his own learning pace. The multicasting reduces the burden on the network and allows as many users as possible to review and assess their training experience. This application carries over into numerous other scenarios. Training and communication can be done online, at any time of the day, at prices far below those offered by conventional means of resident and non-resident Military Occupational Specialty (MOS) schools and Professional Military Education (PME).

D. SUMMARY

Multicasting gives us a high performance, reliable distribution model for delivering information, coupled with a tool for integrating the information into a force enhancer. The biggest advantage that can be realized is developing a Common Tactical Picture in real-time. This will require additional research as discussed in the final chapter.

VI. CONCLUSION AND RECOMMENDATIONS

A. DISCUSSION

As dictated by the Commandant, the Marine Corps of the 21st Century is being redesigned to better leverage information technology to synchronize its force while increasing the lethality of its weapons and the survivability of the force itself.

Multicasting, its associated applications, and its communications infrastructure provides the Marine Corps with a cost effective, distributed collaboration and dissemination capability that also supports current network applications.

The thesis has discussed the use of a new technology which enables bandwidth savings for the purpose of enhancement of situational awareness. A thorough examination of the baseline mechanics and capabilities was conducted to identify potential applications within the United States Marine Corps. These applications were based on government and industry scenarios of successful multicast implementation.

Multicasting's success within the Marine Corps will depend heavily on three factors: 1) its ability to utilize existing infrastructure; 2) accessibility to all force levels of organization; and 3) development of software applications that can harness its full potential.

During examination of multicasting's capabilities, several assumptions were made regarding its transmission through existing communications infrastructure, specifically, the ability to deliver real-time, synchronized applications down to the tactical level.

The use of the existing infrastructure is central to the success of any technology implementation. The Marine Corps has invested heavily in recent years to develop a robust communications infrastructure. All systems that are targeted for implementation

must be capable of utilizing the existing infrastructure. Additional investment to increase the capabilities of the current infrastructure is viewed as financially and technically impractical.

The open standards of multicasting makes it possible to provide communication and information services over current communication paths with Marine Corps equipment. For force synchronization and maximization to occur, all personnel within the Marine Corps must have access to real-time, reliable information. This is particularly critical in the objective area, but necessary within supporting units as well. The critical importance of integrated databases and information maintenance cannot be understated. Applications must be built which are scaleable and capable of storing and accessing a wide variety of data formats through various transmission means. Identifying information requirements and building robust databases that support the storage of this information is essential to achieve the benefits multicasting offers.

B. RECOMMENDATIONS

Building on these products, further research should concentrate on application development and tactical delivery. These research areas should parallel current trends in industry and as such, should not be limited to traditional notions of organizational structure, reporting relationships, and command hierarchies. Research is continually advancing. The Department of Energy is working on a multicast-enabled application that allows real-time remote control of instruments over a network [Ref. 16]. This has obvious implications within the DoD for weapons systems, monitoring equipment, and interdepartmental collaboration. Future applications include collaboration, database

synchronization, and training. These types of applications are currently available in various off the shelf configurations.

Examples include real-time information systems that coordinate and facilitate the command and control functions of maneuver and logistics. Commanders supported with a continuous, timely flow of information could accurately monitor resources from many locations simultaneously, releasing personnel from traditional administrative functions to focus on mission critical events.

C. CONCLUSIONS

IP Multicasting is a major standards-based solution that can support thousands of users simultaneously with substantial bandwidth and cost savings when compared with current TCP/IP networks. Multicast applications can improve response times and lead to dramatic reductions in cost of materials and personnel. [Ref. 17] Multicasting can provide the Marine Corps with a significantly improved capability to perform its mission, enhance evolutionary developments, incorporate new technologies, evaluate commercial products, and improve overall combat effectiveness.

As with any new technology, it will take time before multicasting is universally accepted within DoD. In the case of its ability to deliver cost effective simultaneous distribution of information, multicasting should be recognized and immediately incorporated into the Marine Corps communication infrastructure.

Page Intentionally Left Blank

LIST OF REFERENCES

1. *Concepts and Issues 99,* United States Marine Corps, 1999.

2. Concurrent Computer Corporation, *The Impact of Digital Video Servers on Broadcast Studio Efficiency, Profitability, and Growth*, 1997.

3. Cisco Systems, *Overview of IP Multicasting*, 1998.

4. Kingston Satellite Services, *Digital Video Broadcasting*, 1998.

5. Uunet Technologies Inc., *UUCast Multicast Service*, 1998.

6. IP Multicast Initiative, *How IP Multicast Works,* 1997.

7. IP Multicast Initiative, *Higher Level Protocols used with IP Multicast,* 1997.

8. Mazda, F. F, *Telecommunications Engineer's Reference Book*, Butterworth-Heinermann Ltd., 1993.

9. Optibase Inc., *MPEG Primer*, August 1997.

10. Optibase Inc., *Using Optibase Encoders/Decoders*, August 1997.

11. Waring, B., "Streaming Video," *New Media Magazine*, v. 9, Issue 4, April 1999.

12. Microsoft Corporation, *Microsoft Multicast IP & Windows Media Technologies Deployment*, 1998.

13. Starlight Networks Inc., *Accelerating High-Value Business Process with Streaming Video*, December 1997.

14. May, P., "Multicasting," *Network Magazine*, v. 14, Issue 2, February 1999.

15. Duncan, M. A., *An Analysis of Bandwidth Requirements for Collaborative Planning*, Master's Thesis, Naval Postgraduate School, Monterey, California, June 1998.

16. *Networked Computing for the 21st Century*, Subcommittee on Computing, Information, and Communications R&D, 1998.

17. Goncalves, M. and Niles, K., *IP Multicasting*, McGraw-Hill, 1999.

18. Boyd, J., *Destruction and Creation,* 1976.

19. *Commander's Common Tactical Picture Guide for GCCS,* Draft, Joint Chiefs of Staff, 1998

20. Gates, B., "Business at the Speed of Light," [http://www.speed-of-thought.com/getting/explore.html], 1998.

21. Presentation, *West '98*, U.S. Naval Institute, 1998.

BIBLIOGRAPHY

Boyd, J., *Destruction and Creation,* 1976.

Cisco Systems, *The Fundamentals of IP Multicasting*, 1998.

Cisco Systems, *Overview of IP Multicasting*, 1998.

Cisco Systems, *IPTV Data Sheet*, 1998.

Commander's Common Tactical Picture Guide for GCCS, Draft, Joint Chiefs of Staff, 1998

Concepts and Issues 99, United States Marine Corps, 1999.

Concurrent Computer Corporation, *The Impact of Digital Video Servers on Broadcast Studio Efficiency, Profitability, and Growth*, 1997.

Gates, B., "Business at the Speed of Light," [http://www.speed-of-thought.com/getting/explore.html], 1998.

Globalcast Communications, *Multicast Distribution Engines*, 1998.

Goncalves, M. and Niles, K., *IP Multicasting*, McGraw-Hill, 1999.

Real-Time Imaging, IEEE Press, 1996.

International Conference on Image Processing, v. 2, IEEE Press, 1998.

IP Multicast Initiative, *Higher Level Protocols used with IP Multicast,* 1997.

IP Multicast Initiative, *How IP Multicast Works,* 1997.

IP Multicast Initiative, *IP Multicast: Glossary of Terms,* 1997.

IP Multicast Initiative, *Managing IP Multicast Traffic: A First Look at the Issues, Tools, and Challenges,* 1997.

IP Multicast Initiative, *Writing Multicast-enabled Applications,* 1997.

Kingston Satellite Services, *Digital Video Broadcasting*, 1998.

May, P., "Multicasting," *Network Magazine*, v. 14, Issue 2, February 1999.

Mazda, F. F, *Telecommunications Engineer's Reference Book,* Butterworth-Heinermann Ltd., 1993.

Microsoft Corporation, *Microsoft Multicast IP & Windows Media Technologies Deployment*, 1998.

Networked Computing for the 21st Century, Subcommittee on Computing, Information, and Communications R&D, 1998.

Optibase Inc., *MPEG Primer*, August 1997.

Optibase Inc., *Using Optibase Encoders/Decoders*, August 1997.

Stardust Forums Inc., *Internet Bandwidth Management,* November 1998.

Starlight Networks Inc., *Networked Video in Three Easy Steps*, August 1997.

Starlight Networks Inc., *Accelerating High-Value Business Process with Streaming Video*, December 1997.

Uunet Technologies Inc., *The Business Potential of the Internet*, White Paper, 1998.

Uunet Technologies Inc., *UUCast Multicast Service*, 1998.

Waring, B., "Streaming Video," *New Media Magazine*, v. 9, Issue 4, April 1999.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center 2
   8725 John J. Kingman Rd., STE 0944
   Ft. Belvoir, Virginia 22060-6218

2. Dudley Knox Library..2
   Naval Postgraduate School
   411 Dyer Rd.
   Monterey, California 93943-5101

3. Director, Training and Education...1
   MCCDC, Code C46
   1019 Elliot Rd.
   Quantico, Virginia 22134-5027

4. Director, Marine Corps Research Center...2
   MCCDC, Code C40RC
   2040 Broadway Street
   Quantico, Virginia 22134-5107

5. Director, Studies and Analysis Division..1
   MCCDC, Code C45
   300 Russell Road
   Quantico, Virginia 22134-5130

6. C4I Systems Architecture and Standards Branch (CSA) 1
   HQMC C4I
   2511 Jeff Davis Highway
   Suite 2500
   Arlington, Virginia 22202

7. Dr. Syed Ali, DISA Chair 1
   Mail Code CC/Sa
   Department of Joint Command Control Communications and Intelligence
   Naval Postgraduate School
   Monterey, California 93943

8. LtCol Terrance Brady 1
   Mail Code IS/Ba
   Department of Systems Management
   Naval Postgraduate School
   Monterey, California 93943

9. CAPT Hauser USN.. 1
DISA HQ/D6 Chief of Staff
701 S. Courthouse Rd
Arlington, Virginia 22204

10. Captain Mark Flournoy (Code 36)... 2
Box 133
Abbeville, Alabama 36310